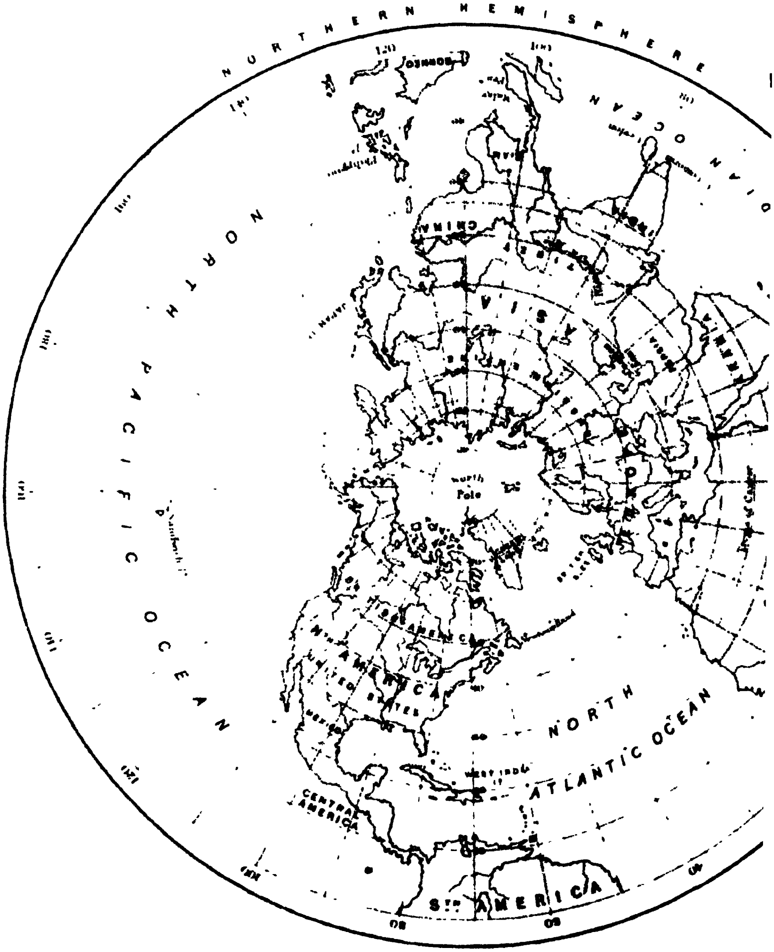
"WHENEVER A NEW AND STARTLING FACT IS BROUGHT TO LIGHT IN SCIENCE, PEOPLE FIRST SAY 'IT IS NOT TRUE,' THEN, THAT 'IT IS CONTRARY TO RELIGION,' AND LASTLY, 'THAT EVERYBODY KNEW IT BEFORE.'"

—*Professor Agassiz.*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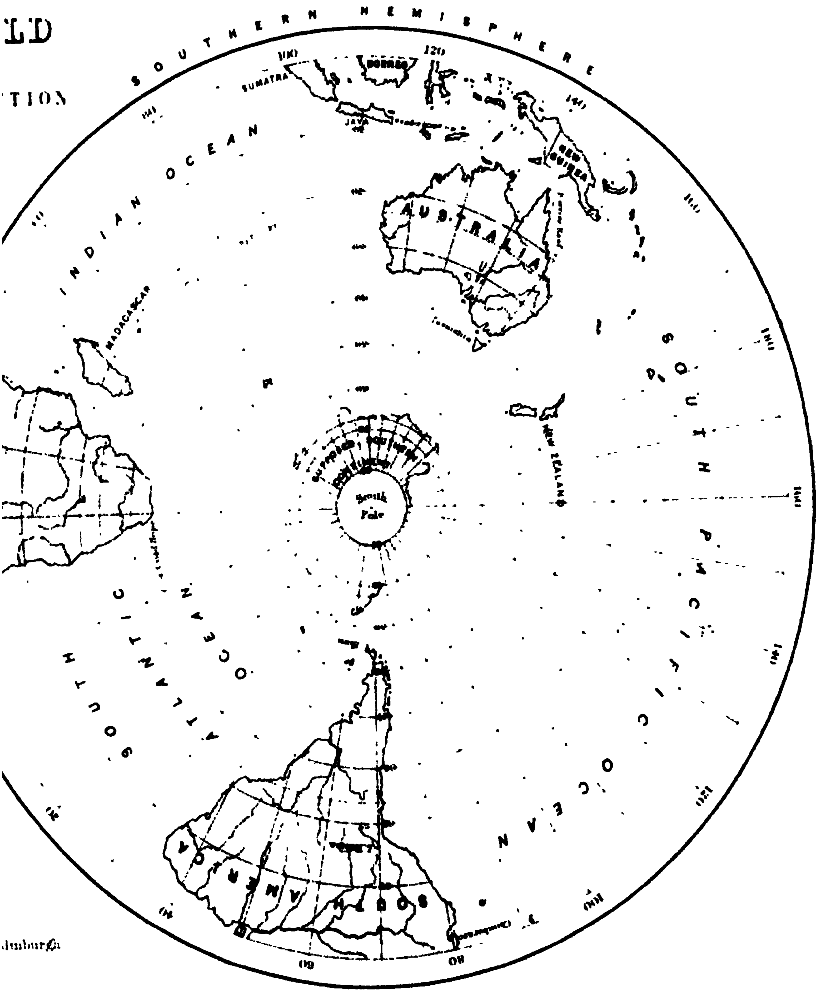

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THE

ORIGIN OF THE SEASONS

CONSIDERED FROM A

GEOLOGICAL POINT OF VIEW

BY

SAMUEL MOSSMAN

AUTHOR OF 'CHINA, ITS HISTORY AND INSTITUTIONS,'
'OUR AUSTRALIAN COLONIES,' ETC. ETC.

WITH A MAP AND DIAGRAMS

WILLIAM BLACKWOOD AND SONS
EDINBURGH AND LONDON
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INTRODUCTION.

Among the natural phenomena in the physical world of practical importance to mankind, none, perhaps, have engrossed public attention in all civilised nations more than the ever-recurring, ever-changing vicissitudes of The Seasons. This has been especially the case in the islands and continent of Europe, from the most ancient times up to the present day, in consequence of Spring, Summer, Autumn, and Winter being more equal in their division of the year than in the other temperate regions of the north and south hemispheres. Moreover, if there be any nation more than another where the seasons, with their varied phenomena, troop most regularly in succession, and are most distinctly typical of all their vicissitudes throughout the year, our own United Kingdom, embracing all the British Isles, ranks first upon the calendar. It must be admitted, however, that the proverbial changeableness of our insular climate, compared with the average regularity of continental ones, frequently disturbs the progress of the seasons in pursuing the "even tenor of their way," when a wintry day

will sometimes rush in with snowy garb upon the leafy blossoming trees of summer. But even these exceptions to the rule enhance the interest we attach to the study of that universal theme, *The Weather*, which emanates from them, and in which all classes of society find a topic of daily consideration, more or less important as it enters into the business of life, affecting their pursuits in raising food for subsistence, or the enjoyment of health and comfort. Hence the vicissitudes of the seasons from day to day are matters of universal interest and remark from the peer to the peasant, and almost everybody professes to have some special opinion regarding their effects upon vegetation and animal existence. Yet it will be found, by any one who takes the trouble to inquire, that few people, even educated persons, are cognisant of the immediate cause from whence the seasons spring.

Perhaps this arises from the technical and abstruse method used by astronomers in describing the inclination of the earth's axis, its diurnal revolution, annual rotation, and attendant phenomena,—"Phenomena of great interest to the inhabitants of the earth—phenomena which have their source in the double movement of our planet. From one day to another the inhabitants of the same place—let us rather say the inhabitants of the same latitude—see the sun ascend above the horizon to variable heights. The points in the east and west where the radiant body rises and sets change their places, the sun at noon attains a greater or lesser altitude and the length of its daily sojourn above the horizon gives to the days and nights their variable and

unequal lengths; hence different temperatures and diversified climatic conditions—hence *The Seasons.*" Even this apparently simple astronomical description fails to impress the mind with a clear substantial view of the terrestrial cause which produces the phenomena. Prominence is given to the apparent motion of the sun, while the peculiar angle of the earth's axis, which is the true cause of the seasons, is left in the background. It is with a view to render the question more interesting and impressive to the general reader that the following method of treating it upon geological principles has been adopted. Not, be it understood, with the intention of superseding the researches of astronomers where they prove the movements and perturbations of the earth and her sister planets, by mathematical demonstration, to affect the revolution of the seasons. On the contrary, it is with a desire to unite the principles of the modern study of geology with those of the more ancient science of astronomy, that we venture on propounding a new theory, believing that henceforth the two sciences must be associated to obtain a full explanation of the phenomena of the universe.

Hitherto geology has been considered in some measure antagonistic to astronomy; but now, as the investigations of geologists unfold the past physical condition of the earth, the records exhumed furnish data for ascertaining more correctly the nature and substance of the planets. Aided by powerful telescopes, observers are now beginning to form an accurate idea of the moon's geology. Portions of meteoric stones that have reached the surface of our planet have been examined, and found

to contain minerals analogous to those composing our sedimentary rocks, from which it has been inferred that they belonged to heavenly bodies similar to the earth, having passed through geological epochs of the same character. On the other hand, the planets are shown to present different degrees of inclination in their axes of rotation as compared with that of our own, thereby furnishing data for inquiry as to whether the earth may not have at some period passed through greater or lesser angles of displacement from a normal condition. Thus may the two sciences go hand in hand, and produce an astro-geological study of the past history of our planet, to find the true origin of the seasons. By examining the structure of the earth's crust, and the unequal distribution of its protuberant masses of land, we may infer that internal volcanic forces have exercised more influence in producing the aberration of its axis than all the external perturbations of the planets. It is upon this basis we ground our geological theory, that the world has all along possessed within its own sphere the power of altering the inclination of its axis, and thereby producing those charming vicissitudes in temperate regions. Moreover, the same power that produced the present inclination, there are data to infer, has in former periods extended that angle, and produced the inexplicable phenomenon of tropical life having once reigned in latitudes where it is no longer seen.

Astronomers inform us that the angles of displacement between the planes of the equator and the orbit of our planet are diminishing according to a geometrical ratio, based upon observations and records for the past

two thousand years. In other words, the present limit of the tropical zones, defined upon ordinary maps of the world at twenty-three degrees and a half of latitude north and south of the equatorial line, is less than it was formerly, and its annual diminution can be ascertained by the delicately-graduated instruments in our observatories. It is true the diminution within a year is infinitesimal, but in the course of many thousands of years it accumulates to a whole degree, so that in time the torrid zone may contract, and the heat concentrated within its circle become gradually diffused through the temperate zones, which, accordingly, would widen in proportion. On this basis, if we trace back the ratio of diminution into the fossil records of geological time, there is abundant evidence to show that the tropical belt at one period extended far beyond its present limits, even to the latitudes of the British Isles, or at all events to double the extent of the Tropic of Cancer. At this period, the four seasons, as they are now calculated upon our almanacs, were not in existence. Europe was subject to climatic influences similar to those prevailing at present in the tropical regions of Africa or America; and it was not until the flora and fauna of that period became extinct, after flourishing through successive dry and rainy seasons, that these were broken up into four divisions, introducing a new order of things into the vegetable and animal kingdoms. Notwithstanding the many evidences in astronomy and geology that the reign of the seasons has been of recent origin in the physical history of the earth, it seems to be a foregone conclusion, almost universally entertained, that they have existed from all

time. It is the purpose of the following Essay to advance an opposite theory, as the basis of a better explanation of the varied phenomena connected with the past and present history of the seasons.

Hitherto the observations of writers upon this subject, and to a certain extent the investigations of meteorologists and hydrologists bearing upon it, have been chiefly confined to the physical geography of the north as compared with the south hemisphere, they having apparently come to the conclusion that the natural phenomena of the one are a counterpart of the other. This is easily explained, as it is only within a very recent period, almost within the present generation, that the attention of scientific men has been directed to the regions at our antipodes, or generally south of the equator. Now, however, the spirit of investigation is alive in these golden regions, attracting learned men from all parts of Europe, through the liberality of the local governments, who furnish yearly reports, showing, in a general sense, that considerable disparities exist between the two great divisions of the globe, besides the inequality in the distribution of land and water at the level of the sea. From these and other reports by independent observers, we obtain sufficient data to advance the hypothesis that in each hemisphere there are separate systems of currents in the sea and air, which, although following the same natural laws, yet in their operations are so widely different that not only are the seasons reversed, but the constituents of the atmosphere exist in different proportions. Having resided for many years in different parts of the south hemisphere, the Author made it his study

to compare its physical aspect with what had come under his observation in the north hemisphere, from the far East to the western confines of Europe. It has occurred to him that, if their disparities were brought forward in prominent contrast, much valuable information might be elicited for the benefit of individuals and communities as well as science; and on these grounds he ventures upon discussing and differing from the opinions of learned men in the following pages, when these appear to be inconclusive.

Among the undetermined questions opened up in these pages is that of geologists regarding the magnitude of the internal forces of our planet in modern times; of the violence of which, during the latter part of 1868, so many and such widespread manifestations have been felt on the surface. On this point it has been remarked that "the evidence which the earth's action has afforded us in that year goes far to overthrow the theory which, forty years ago, was almost universally accepted by geologists, that the earth's internal fires are becoming gradually extinguished. It would be difficult to point to any year within the past ten centuries in which we have had so many and such important evidences of the energy of the earth's internal action." Without endeavouring to revive the discussions on this question, the Author thinks it a favourable opportunity to consider the degrees of volcanic energy in the south hemisphere as compared with those in the north, together with the probable depths of the volcanic seats of action which produced the disastrous earthquakes in South America, California, the Sandwich Islands, the West Indies, and

southern Europe, within the course of a few months. On these and cognate questions it will be shown in the progress of the work that their consideration is not confined to science, but becomes a matter of public importance. With a view, therefore, to render his explanations perspicuous and interesting to the general reader, the Author has treated the whole subject in a popular manner.

EDINBURGH, 1869.

LIST OF DIAGRAMS, AND MAP.

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PART I.

THE LAND

CHAPTER I.

CONFIGURATION OF THE LAND ABOVE AND BELOW THE SEA.

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Upon ordinary maps of the world the configuration of the land is superficially delineated, as it appears at the level of the sea, with radiating lines intended to convey an approximate idea of the elevation of mountains above that level. Until recently the study of geography has been confined to the surface of the earth visible above its waters; and though, from time to time, some bolder inquirer than his neighbour has speculated upon the possible form of the land hid from view under the depths of the ocean, yet for all practical purposes geographers formerly ignored the existence of submarine

geography. It was not until Humboldt and other eminent men of science turned their attention to this neglected sphere of observation, that the configuration of the land *below the level of the sea* was pointed to as an important practical study in the extended science of Physical Geography. Accordingly, hydrographers of all nations volunteered their services to solve the great problem. They soon determined that the sea is not unfathomable, as hitherto supposed, for they have reached some of its profoundest depths with skilfully-invented instruments, which have brought up minute shells of *infusoria* from the basin of the North Atlantic at depths reaching to six miles. Further, from a series of soundings across the land it flows over between the British Isles and America, it has been shown that the ocean bed is diversified by hills and valleys, table-lands and precipitous crags, just as these geographical features of the land present themselves above the level of the sea. Moreover, the entire basin of the Atlantic forms in itself a vast submarine valley, of which that portion between Ireland and Newfoundland is about two thousand miles wide, and nearly three miles deep at its lowest part. Hence a person standing on the island of Valencia on the west coast of Ireland is about the same distance and elevation above the bottom of the Atlantic—across which the telegraph cables lie—that the summit of Mont Blanc is above his position. And if the bed of the ocean were dry, and he were to descend to the bottom, he might traverse as varied a region as that which lies above the level of the sea between him and the highest peak of the Alps. Consider, therefore, at what a giddy height we are perched above the real *terra firma* base of the mountains forming the eastern slope of the Atlantic valley. Like some of the cities built far up in the Andes, near the line of perpetual snow in the tropics, London would be situated among these mountains, of which the Scottish peaks would form the summit of the British groups at an elevation of 20,000 feet.

2. *Stupendous Elevations and Depressions of the Earth's Crust.*—But even this stupendous inequality on the earth's

surface is not its greatest elevation or depression. There are other points at the sea-level where the mountains inland rise on the one hand to double the height of the Alps, and on the other hand the bed of the ocean reaches to twice the depth of that just indicated. Such a position exists at Point de Galle in Ceylon, or, more appropriately perhaps, Cape Comorin, at the extreme verge of Hindostan, where the observer stands between the Himalaya Mountains and the central bed of the Indian Ocean. Gaurisankar, the monarch of the Himalayas, and the highest mountain in the world, is 29,000 feet above the sea; while the greatest ascertained depth of the ocean is upwards of 35,000 feet. Here then we have a depression and elevation of the land 12 miles in perpendicular height. However, as the distance between the two extremes is not far short of 2000 miles, this indentation of the earth's crust would not appear greater in proportion than that between the Alps and the bed of the Atlantic already given. A more striking example of precipitous elevation and depression exists between the highest peaks of the Andes and the bed of the Pacific Ocean adjacent, where they rise "like a wall on an immense crevice," as Humboldt remarks, which is not less than eight miles in perpendicular height in a distance of about 200 miles by horizontal measurement.

3. *Centrifugal Force of Elevated Lands and Mountain-Chains.*—In this manner we obtain a more correct view of the greatest inequalities of the earth, and, what is important, we are enabled to form some estimate of the *leverage*, or increase of rotating power, the world acquires from these stupendous mountain-chains, which whirl with centrifugal force at the extreme verge from its centre. These extremes of elevation and depression are pointed out to show that the ordinary method of calculating the heights of table-lands and mountains above the level of the sea, does not furnish a correct basis for the elucidation of our geological theory as to the origin of the seasons being the result of disparity in the earth's hemispherical equilibrium. Consequently we have prepared a diagram delineating a section of the world, exhi-

biting an approximate outline of its solid form above and below the level of the sea. In like manner a map of the world on the same projection would show that the three great oceans—the Atlantic, Indian, and Pacific—are only vast valleys filled with water. If, therefore, at the outset, the reader will look at the solid matter of the world from a subaqueous point of view, as he does at present from a subaerial position, he will better understand the force of the propositions advanced. It is nothing new to treat water simply as a denser medium than air—as one of the great supporters of animal life, which is inhaled and exhaled by gill-breathing fishes as the atmosphere is by lung-breathing animals.

4. *Their General Aspect from the Bottom of the Sea.*—Viewed in this light, how the bulk of each island and continent expands—not merely doubling itself, but increasing five and ten fold at the base as compared with the apex visible above the sea. Here some solitary rock in the Atlantic becomes the pinnacle of a rocky mountain-chain like that which fringes the coasts of America; there a "fairy isle" in the Pacific crowns the summit of a volcanic cone that rivals Chimborazo; while the great Barrier Reef, off the east coast of Australia, becomes a mountain-chain like the Cordilleras of South America. So, in proportion, are the continents enlarged in area and elevation. The table-lands of Mexico assume gigantic proportions as they rise from their base in the two ocean-valleys of the North Atlantic on the east, and the North Pacific on the western slope. Europe and Africa would be as one continent, with the Mediterranean, about half its present depth and area, a lake in the mountains, 10,000 feet above the valley of the Atlantic, as Lake Titicaca now lies above the lower valleys of South America. But that region which would show the most remarkable inequality on the configuration of the earth, is where the table-lands of Tibet, forming the central plateau of Asia, with the crest of the Himalayas, would be augmented in elevation to 45,000 feet above the lowest ocean-valleys, and form almost a semi-hemisphere of the earth's crust above the sea-bed averaging

20,000 feet in height. This enormous increase will be more apparent if we take into consideration the average elevation of the Asiatic continent, as determined by Humboldt at not more than 1150 feet above the level of the sea. By this process of calculation the bulk of this great *excrescence of the world*—if we may so term it—in the north hemisphere, having no equivalent or counterpoise in the south, is augmented to such a degree that its dimensions appear only exceeded in greatness by all the land itself above the sea-level. Yet we are led to suppose that this vast preponderance of solid matter—of massive rocks whose specific gravity is three or four times that of water—towering up to peaks ten or twelve miles in vertical height above their bases—spreading over half the superficies of the north hemisphere—that this inconceivable bulk of heavy solid matter has no more influence over the rotation of the world than if it were so much air and water.

5. *Cubic Contents and Absolute Weight of the Earth.*—The solid contents of the earth have been computed at upwards of 259,000 millions of *cubic* statute miles, and its absolute weight at about 5842 trillions of tons. Of these totals the sea comprises 788 millions of cubic miles; and for its mass or weight (taking the specific gravity of sea-water under a pressure of two miles at 1050), 3,270,600 billions of tons, or one 1768th part.* These estimates are based upon the average specific gravity of the terrestrial substance calculated at $5\frac{1}{2}$ to 1 of water. They include the ocean, but we are not certain whether the weight of the atmosphere is comprised in the general average. This, however, is immaterial, as the aerial envelope is only 1,125,000th part of the total mass of the earth, weighing something over the 200th part of 1 trillion tons. Taking these estimates of the bulk and density of our planet as a whole, they have been chiefly used for astronomical purposes, in computing the perturbations of the earth on the other members of the planetary system. We may, with equal propriety, apply them to the purposes of physical geo-

* Art. "Physical Geography," 'Encyclopædia Britannica.'

graphy, as bearing upon our theory of unequal hemispherical equilibrium. For example, if we can imagine the earth divided into two hemispheres through the equatorial line, just as we would divide a lemon in the middle, it will be found by computation that the north hemisphere is considerably heavier than the south. As regards the precise difference, the present state of our knowledge regarding the profound depths of the ocean can only lead us to an approximation towards the truth. Enough is known, however, to venture upon a calculation for the sake of illustrating our theory, trusting that it may suggest to some competent geometrician the formula for a more correct computation and solution of the problem.

6. *Disparity between the Solid Bulk of the North and South Hemispheres.*—In forming a basis for such an estimate, we must not go by the ordinary superficies of land and sea, given in round numbers as one of the former to three of the latter. We must endeavour to find the bulk of the upper strata of the earth's crust at corresponding depths with the ocean, and strike an average for area and depth, say of four miles below its level. Taking all things into consideration, we assume an approximate average of the hemispheres being equal. Then, by dividing each hemisphere into three parts, we may estimate the north as containing 2 of land and 1 of water, and the south 2 of water and 1 of land. According to the above calculation of the earth's absolute weight, an average half contains 2921 trillions of tons. But, as we find the preponderance of heavier matter in the north, we must add the excess of weight on the one hand to it, and deduct the deficiency on the other from the south, in consequence of the lesser weight of its aqueous preponderating contents, to ascertain the disparity of the external hemispherical equilibrium. Having secured our ground so far, it remains, to complete our formula, to take the average specific gravity of the rocks at the *mean* pressure of the sea, as 4 to 1 of water, or 1½ less than the aggregate—5½ to 1 of the whole terrestrial globe—according to Laplace.

7. *Estimated Difference in Weight.*—On this basis we have to add six times the weight of water in the north hemisphere, which is equal to one-third of the whole ocean, or 1,090,200 billions of tons, making, in even figures, 6½ trillions—thereby augmenting the absolute weight to 2927½ trillions of tons. According to the same ratio, the south hemisphere is reduced to 2914½ trillions of tons Thus we have a disparity of 13 trillions in absolute weight between the two hemispheres, equivalent to about four times the gravity of the entire ocean; or the 450th part of the solid earth added to the northern half over the southern, and thereby overbalancing its axis This view of the disparity between the weight of the solid fabric of the globe, when divided at a right angle to its axis of rotation, illustrates the enormous difference between the land seen above, to that which forms its basis below the level of the sea. As in an iceberg floating on the deep the spectator beholds only one-ninth of its crystalline substance above the water, so do we see in the continents and islands less than one-twentieth of their bulk, reaching down to its profoundest depths.

8. *The Magnitude of Land upheaved, Evidence of Inconceivable Volcanic Force.*— Although this unequal division in the absolute weight of the terrestrial sphere doubtless exercises its influence on the inclination of its axis, yet we do not claim this power in repose as equal, in the smallest degree, to the disparity in action that must have existed during the early geological epochs, when the accumulated internal forces first upheaved the vast continental masses in the north compared with those in the south. What, for example, must have been the incalculable volcanic forces which at different periods acted within the earth when the crystalline rocks of the Himalayas were upheaved! Let the observer rise to these in contemplation, even their magnitude above the sea-level, and some idea of this force must impress his imagination Standing within the shadow of the prismatic rocks that support the roof of Fingal's Cave at Staffa, he may estimate the force that upheaved that fretted roof by

calculating the amount of animal strength and machine force that was required to raise the dome of St Paul's. From this basaltic isle he may travel to the mainland and ascend Ben Lomond or some other of the Highland mountains, where precipitous crags dwarf the rocky cliffs he has left, the agency that upheaved which must have been proportionately as much greater than that which raised the isle. From the Highland mountains let him ascend the Alps, and look down from their peaks—piercing the rare atmosphere above the line of perennial snow—and gauge, if he can, the tremendous forces which could have upheaved to such a height that mass of igneous rock, as much surpassing the Highland mountains as these do "famed Staffa's Isle." But even these become of far inferior magnitude if he journey to the summit of the Himalayan crest or the chain of the Andes. "If we were even to picture to ourselves Mount Pilatus placed on the Schreckhorn, or the Schneekoppe of Silesia on Mont Blanc, we should not have attained to the great colossus of the Andes, the Chimborazo, whose height is twice that of Mount Etna; and we must pile the Righi or Mount Athos on the summit of the Chimborazo in order to form a just elevation of the Dhawalagiri, the highest mountain of the Himalaya."* The elevated mass of land forming the whole of this vast group and the table-lands on which it is piled, as far transcends the Alps in density and bulk of rock as it does the Highland mountains: and as Fingal's cave is only a portion of the isle—the Scottish Highlands a part of Great Britain—the Alps a section of Europe—so are the Himalayas only a division of the Asiatic continent; while that vast region is rivalled in area by Africa, and in elevation by America. It is almost impossible for the human mind to grasp the cubic measurement of these protuberances of land that bulge out from the spheroidal form of the earth; or to estimate the tremendous internal force overcoming the law of gravitation which upheaved them to their present elevation.

* Humboldt's 'Cosmos.'

9. *Accumulative Power of Internal Forces.*—It must not be supposed, however, that these internal forces were exercised at one time. On the contrary, geology teaches us that ages elapsed in the upheaval of rocks between one epoch and another. Nevertheless, the disturbing influences of these forces upon the revolution of the earth we take to have succeeded each other in the same direction, and thus to have become cumulative in the displacement of its axis. Once an upheaval was made through the stratified rocks lying in a horizontal position on a certain part of the globe, it follows logically that others continued in the same line of disruption simply because a fissure was made through which the first molten mass was ejected. As to why the primary forces were greater in a northern direction than in a southern point from the earth's centre we are not prepared to say; but it is very probable that the law of universal gravitation, acting through the attraction of some heavenly body, drew the incandescent matter of the earth towards the surface, where it now preponderates in its solid state. So far our theory is in harmony with that of the astronomers, who attribute the obliquity of the ecliptic and its diminution to celestial perturbations.

10. *Lyell's Geological Theory considered.*—On the other hand, the most advanced school of geology, founded by Sir Charles Lyell, holds that at no period of the earth's geological history are there data for assuming that the volcanic forces were more powerful than at the present day or during the historical era. On this point that eminent geologist remarks:—"As we enlarge our knowledge of the ancient rocks formed by subterranean heat, we find ourselves compelled to regard them as the aggregates of innumerable eruptions, each of which may have been comparable in violence to those now experienced in volcanic regions. It may indeed be said that we have as yet no data for estimating the relative volume of matter simultaneously in a state of fusion at two given periods, as if we were to compare the columnar basalt of Staffa and its environs with the lava poured out in Iceland

in 1783; but for this very reason it would be rash and unphilosophical to assume an excess of ancient as contrasted with modern outpourings of melted matter at particular periods of time. It would be still more presumptuous to take for granted that the more deep-seated effects of subterranean heat surpassed at remote eras the corresponding effects of internal heat in our own times."* This argument may hold good as far as the mere outpourings of volcanic matter on the external surface of the earth are concerned, but it does not apply to the deep-seated internal forces that first upheaved the land; nor do we deem it "rash and unphilosophical" to consider those forces to have exercised greater power in the north hemisphere than in the south. Here is the evidence before us: there is a preponderance of land in the former, that could only have been upheaved at a remote epoch by central volcanic forces which have not been equalled since; otherwise we would have corresponding elevations in the southern hemisphere, and depressions in the north, under the sea-level, where continents now exist.

11. *Supposed Infinite Duration of Geological Time.*—According to this school of geology, time given, all the phenomena we see in the formation of the mountain-systems of the world are observable at the present period. "In regard to subterranean movements, the theory of the perpetual uniformity of the force which they exert on the earth's crust is quite consistent with the admission of their alternate development and suspension for indefinite periods within limited geographical areas. . . . When reasoning on the intensity of volcanic action at former periods, as well as on the power of moving water, geologists have been ever prone to represent nature as having been prodigal of violence and parsimonious of time."* Hence the new doctrine finds a solution for every geological problem in the fathomless abyss of time. Without disputing the authenticity of the fossil records, which furnish data for concluding that vast periods of time must have elapsed during the formation of

* Lyell's 'Principles of Geology.'

the land, still we may question the computations of those enthusiastic geologists who reckon epochs by tens and hundreds of millions of years. Of them it may be said, to reverse Lyell's remark, that they are prone to represent nature as having been prodigal of time and parsimonious of violence. Where two extreme theories are propounded, it is always best to take a middle course, as likely to be nearer the truth than either. On the one hand, while discarding the cataclysms and tremendous convulsions of the old school, we need not altogether accept the new theories of perpetual uniformity throughout all time, even to that bordering on eternity. However much we may appreciate this doctrine of repose, yet it is a law in nature that where force exists it acquires strength by degrees until it reaches a climax, when it gradually expends itself; and hence there are grounds for concluding that the subterranean forces of the earth have decreased in strength and activity from a culminating period.

12. *Laws of Force obscure in Igneous and Aqueous Theories.*—It is an undecided question among geological controversialists whether the internal structure of the earth is at present composed of incandescent rock, and the external part only an outer shell or crust, caused by the refrigeration of the molten mass; or whether it is solid rock to its centre, formed by the gradual deposit of matter during its primary aqueous and gaseous condition, while the stratified rocks thereby formed have generated the internal heat through chemical agencies which forced the igneous rocks to the surface. Into this controversy it is not necessary to enter. Suffice it to say that both theories are based upon the indisputable fact that profound internal forces have existed, and still exist, in upheaving masses of the earth's solid composition from unknown depths to its circumference, far beyond its aqueous spherical form. It has been said, however, that "the word *force* has, in general, some degree of obscurity. It is used to denote the cause of motion; but we have no direct knowledge of it, and we judge of its intensity by the effect of what we suppose it to produce. In all our reason-

ing concerning forces, it is the changes of motion which we measure and compare together, and which are really the subjects of our thoughts. Attraction and repulsion are forces or principles of motion known to us only by the phenomena we observe; but the circumstance of their implying action at a distance is an additional source of obscurity in which other kinds of force do not participate."*

13. *Power of Gravitating Force.*—Notwithstanding the difficulty of defining in the abstract the principles of force and attraction, their attendant phenomena are understood by every one, especially with regard to what is visible on the earth obedient to the law of gravitation. Some idea of the power necessary to overcome the gravitation of bodies to the earth's centre may be formed from the explosive force and concussion of a gun in projecting a bullet to a height where it ceases to ascend, and returns back to the ground with comparatively less speed. Nevertheless this return force, or attraction of gravitation, has considerable power, as military men know from the effects of a shell descending from its culminating point of the arc on which it has been discharged. To overcome this attractive force, the projectile force must preponderate. Hence, in considering the amount of internal force which projected the enormous masses of igneous rock from the central region of the earth to its outer rim, we must calculate the force of gravity by which these were at every instant pulled back in a vertical line. And although this downward force is slight at a short fall, yet it increases with the square of the distance, until a stone descending a height of a few thousand feet acquires the velocity of a cannon-ball at the muzzle of the gun. A melancholy accident during an Alpine ascent, illustrative of this fact, occurred in 1865, when Lord Douglas and some of his companions fell from the summit of the Matterhorn, down a sheer descent of 4000 feet. When the bodies were discovered, portions of the limbs, flesh, and clothing, were cut off as with a sharp knife, and the head of the unfortunate young nobleman was

* Art. "Attraction," 'Encyclopædia Britannica.'

literally driven into the trunk, by coming in contact with a ledge of rock in the fearful descent.

14. *Force of Earthquakes.*—There is scarcely any necessity, however, to adduce comparative phenomena in illustration of the enormous power of this internal force, when we have direct evidence in earthquakes and volcanic eruptions. These furnish active data from which we may compute the dynamic force which raised the primary and secondary igneous formations. "Earthquakes and volcanoes, which stand in intimate connection with one another, are to be considered as the remains of great geognostic revolutions of our globe previous to historical times, rarely changing the place of their appearance, and becoming active at intervals of time varying from an hour to a hundred years."* At what depth this volcanic force originates, or from what immediate cause its enormous explosive and expansive power is derived, there are no satisfactory data to demonstrate. Many theories on this head have been put forth, but most of them are mere conjecture, or without sufficient scientific data to support them. Of its terrible power we have a famous instance recorded in the earthquake at Lisbon, on the 1st November 1755, which lasted not more than five minutes, yet it laid the city in ruins and killed sixty thousand inhabitants. It has been calculated that an area of the earth's surface was shaken on that occasion four times greater than the whole of Europe, extending from the Canadian lakes to the shores of the Baltic and the West Indies. And as an example of volcanic projectile power, we may cite that mentioned by Humboldt, of a solid mass of stone, measuring about three hundred cubic feet, having been discharged from the crater of Cotopaxi, in South America, to a distance of more than eight miles.

15. *Vestiges of former Volcanic Forces.*—In these instances the amount of volcanic force employed must have been something tremendous compared with man's greatest efforts in blasting rocks, or firing heavy ordnance charged with shot

* Johnston's 'Physical Atlas.'

and shell. Yet, when we examine the effects of the forces indicated, the results are comparatively insignificant to those observable on an ordinary basaltic hill, such as that very characteristic mount, Arthur Seat, Edinburgh, 822 feet above the sea-level. And if we continue the comparison to the Alps, and from these to the Himalayas, these vestiges of internal action during the past epochs of the world's history represent an amount of centrifugal volcanic force overcoming centripetal force of gravitation that is only less in proportion to the transcendent velocity of the earth itself in its rotation round the sun, or the diurnal revolution on its own axis in raising its aqueous diameter at the equator 27 miles above the poles.

16. *Humboldt's Estimate of Upheaving Forces.*—Humboldt remarks in his 'Cosmos:'—"Although volcanoes are justly termed in many languages 'fire-emitting mountains,' mountains of this kind are not formed by the gradual accumulation of ejected currents of lava; but their origin seems rather to be a general consequence of the sudden elevation of soft masses of trachyte or Labradoritic augite. The amount of the elevating force is manifested by the elevation of the volcano, which varies from the inconsiderable height of a hill to that of a cone above 19,000 feet in height." In like manner geologists conclude, from inductive reasoning, that the forces which elevated the crystalline rocks of Asia were subject to the same laws. Granite was the active upheaving agent among the older rocks: where it "occurs in large insulated masses of a faintly ellipsoidal form, it is covered by a crust or shell cleft into blocks," an instance of which is met with in Mysore. "This sea of rocks probably owes its origin to a contraction of the surface of the granite, owing to the great expansion that accompanied its first upheaval." *

17. *He points out Evidence of Unequal Internal Forces in the North and South Hemispheres.*—"When the traveller on the declivity of an active volcano—as, for instance, of Vesuvius—examines the frequent partial elevations by which por-

* Leop. von Buch, quoted in 'Cosmos.'

tions of the soil are often permanently upheaved several feet above their former level, either immediately preceding or during the continuance of an eruption, thus forming roof-like or flattened summits, he is taught how accidental conditions in the expression of the force of subterranean vapours, and in the resistance to be overcome, may modify the form and direction of the elevated portions. In this manner feeble perturbations in the equilibrium of the internal elastic forces of our planet may have inclined them more to its northern than to its southern direction, and caused the continent in the eastern part of our globe to present a broad mass, whose major axis is almost parallel with the equator; whilst in the western and more oceanic part, the southern extremity is extremely narrow." *

18. *Application of the Principle involved to account for the Disturbance of the Earth's Equilibrium.*—In this passage the great physical philosopher points out the fundamental principle of the theory herein advanced. If we magnify these perturbations in the volcanic district of Vesuvius to what existed in Central Asia during the upheaval of its table-lands and mountain-chains, we may form some conception of the disturbing forces at that period which caused those "perturbations in the equilibrium of the internal elastic forces of our planet" to which we assign the first impetus given to the earth that altered the angle of the equatorial plane from that of its orbit. Let us consider, for the sake of illustration, that the world, previous to the upheaval of its internal igneous masses of rock, was covered by the sea, without one solitary island breaking the level of its aqueous surface; and that it revolved round the sun with these planes parallel, while the diurnal revolution produced equal day and night. And let us view this terraqueous globe delicately poised in space, with no inequality to disturb the equilibrium of its rotation; when, suddenly, a vast mass of molten rock is driven with inconceivable violence through the crust of stratified rocks which confined the internal volcanic forces,

* Humboldt's 'Cosmos.'

and shakes the whole framework of the globe, which had hitherto enjoyed perfect repose. Then let us suppose that these masses of heavy matter were driven to the surface at each upheaval with cumulative force, so as to raise the superincumbent weight of land in the north hemisphere over that of the south: how easy it is to see that the centrifugal leverage of the mass, and the tremendous concussion from the volcanic action, might prevail to throw the earth out of its equilibrium, until it reached even a greater displacement of the ecliptic than now exists.

19. *Comparative Power of Volcanic Force at its deep-seated Origin and its Exit on the Earth's Surface.*—It may be advanced, in opposition to these views, that we over-estimate the importance of the elevations and depressions of the earth's surface when compared to its absolute weight and magnitude; that the profoundest depths of the sea are less than the smallest indentation on the rind of the smoothest orange, and the highest isolated mountain on the land is but as a grain of sand placed on a terrestrial globe two feet in diameter. Be it so. Nevertheless, these are external indications of internal forces having exercised inconceivable power in the deep-seated alembic of the terrestrial laboratory. In all probability they have arisen from seats of volcanic force near the centre of gravity, from 2000 to 3000 miles below the surface; and in the upward ascent these forces have lessened in the ratio of their projectile motion, as they gradually became neutralised in power by the attraction of gravitation. According to that law of counteraction, internal forces become in a measure expended, and the most violent earthquake or greatest volcanic eruption with which we are acquainted, is but an infinitesimal indication of the deep-seated forces from whence they sprung. The comparative degrees of internal and external volcanic force we have familiarly illustrated by referring to the law of projectile motion exhibited in the discharge of a musket-ball. If the shot be fired perpendicularly from the centre of gravity, the bullet is at first impelled from the muzzle of the gun with such force that it would blow to

pieces the hand that should attempt to arrest its progress. But on reaching a certain distance the projectile force of the bullet becomes expended, and it obeys the more potent power of gravitation. At this culminating point the hand of an infant could catch the bullet with impunity. We have seen this practically exemplified in shooting at an eagle soaring aloft so high that the ball reached him harmlessly without injuring a feather of his wings, which he flapped as it were in derision, sending the deadly messenger back to the ground without having fulfilled its errand. In like manner, sportsmen in Australia, when attempting to shoot cockatoos, which generally perch on the highest branches of the giant trees in the forests of that country, find their largest shot of no avail in bringing down the game, as it rattles on their feathers with less force than a shower of hailstones.

20. *Earthquakes in America furnish Data for Computing the Depths of the Seats of Volcanic Activity.*—Thus we consider that the external elevations and depressions of the land are only comparative indications in degree of the power manifested by the deep-seated volcanic forces that produced them. Therefore it would be a weak argument against our views concerning the stupendous elevations and depressions of the earth's surface to compare Chimborazo to a grain of sand on an ordinary terrestrial globe, without showing that it is but the apex of a vast volcanic vent, which reaches down probably a thousand miles towards the centre of our planet, where its fires are in a state of activity. It may, however, be disputed that there are such deep-seated sources of volcanic energy within the terrestrial laboratory of rocks. Without going into the controversy of the aqueous and igneous theories of the earth, or referring to certain epochs in its past volcanic history, we may safely bring forward the recent calamitous earthquakes in America as an example of the profound depths from whence they spring. The two extreme points affected by the convulsions — in Bolivia to the south, and California to the north — were not less than five thousand miles apart. If

we draw two lines on a section of the earth from these points towards the centre of the earth, making a right-angled triangle near the equator, we have a perpendicular depth of two thousand miles below the sea-level as the possible seat of the volcanic fires that produced this, the widest spread earthquake of which we have any historical record.

21. *Probable Depth of the Volcanic Origin of the South American Earthquakes of* 1868.—It may be said, however, that this is no proof that the source of these volcanic oscillations of the earth's crust are at such profound depths, as the shocks of the earthquakes did not occur simultaneously, and may have travelled from south to north at a comparatively superficial depth. Now it so happened that the intervening region by the line of volcanic action through Central America was not in any way affected by internal shocks, while ten weeks elapsed between the terrible catastrophe in South America and the mild convulsions in the northern continent. This is good evidence that the volcanic forces did not traverse the strata horizontally—at least in a superficial degree,—and forms substantial data in favour of a deep-seated origin. But, irrespective of the earthquake in California, we have sufficient evidence in those of South America to calculate from, as the linear volcanic action extended from the south of Bolivia into Chile, and thence to the north of Peru into Ecuador, a distance approximating to 2500 miles. Along the whole coast within that line the earth was upheaved more or less almost simultaneously on the 13th of August 1868, causing the sea to fall and rise perpendicularly to a height of from thirty to fifty feet, and producing a volcanic wave that swept across the Pacific Ocean to New Zealand and the furthest isles of Polynesia, carrying devastation in its course on land to regions eight thousand miles distant. Taking the centre of this linear volcanic action at an angle of 45° from its extreme points, we have a depth of a thousand miles for the source. But, in order to allow for all possible and unknown aberrations of this mysterious power, if we reduce that to one half, and take an average

depth of the volcanic seat at five hundred miles below the surface, we may estimate the tremendous projectile power of the internal forces at their source that could have produced such commotions on the external crust of the earth as are recorded in the annals of South America during the memorable earthquakes of 1868.

22. *Concluding Remarks on Volcanic Force as a Motive Power in the Movements of our Planet.*—Without referring more particularly to the widespread volcanic phenomena throughout the world during the latter part of that year, we may point out the evidence they furnish of existing internal forces radiating from the central regions of our planet. In August the South American earthquakes occurred; in September Vesuvius was in its third state of activity during the year; on the 8th of October a shock of earthquake was felt at Hiogo, in Japan; on the 25th of that month a similar occurrence overthrew some buildings in San Francisco, California; and about the same time slight but perceptible shocks were experienced in England. Considering the distant points of these indications of volcanic force, some of them antipodal in their position, and the limited period of time during their occurrence, it is not unphilosophical to conclude that this activity was not only deep-seated, but may have sprung from the very centre of the earth itself, radiating its projectile motion to the surface, and overcoming the attraction of gravitation in a perpendicular line of nearly four thousand miles. If, then, we have data in modern times to support a theory of cosmical volcanic activity throughout the solid framework of the earth, may we not with equal propriety conclude that before these forces were lessened in power by the refrigeration of the molten rocks through which they acted, the shocks of earthquakes were proportionally great as the external crust was thinner than it now is? And shall it be said that these inconceivable forces had no influence on the movements of our planet?—that this mission was fulfilled in simply piling up the hills and depressing the valleys

under the canopy of the air, or forming basins for the waters of the sea? However grand we may regard that terrestrial energy in varying the physical geography and natural phenomena of the earth, we believe that these internal forces have also served, and continue to serve, the still more sublime purpose of regulating the vast geological year in our planet, of which the epoch of the seasons is its latest manifestation.

CHAPTER II.

CONFIGURATION OF THE LAND ABOVE AND BELOW THE SEA.—*Continued.*

Pyramidal form of continents, § 23.—Ancient views on the subject, 24 Modern observations, 25.—Humboldt traces this form in all continents, 26.—His views on the cause of this phenomenon, 27.—The probability of its being a general law in nature, 28. This form augmented in the continents below the sea-level, 29. Probable pyramidal form of lunar continents, 30.—Sinking of the land, 31. Darwin's observations in the Pacific Ocean, 32.—Subsidence and elevation of land in Sweden and Finland, 33.—Geological subsidence in the North Atlantic basin, 34.—Humboldt on the causes that change forms of continents, 35. Probable changes that occur below the sea level, 36. Antipodal equivalents of elevation and depression in the earth's crust, 37. Controversy regarding the equiponderance of continents, 38. Proofs that the equipoise of the earth is not maintained, 39. Origin of maps on east and west hemispherical projection, 40.—Figure of the earth shaped more like a lemon than an orange, 41. The form and rotation of the earth seen in a top spinning, 42. Diagram illustrating theory of unequal poise in the earth's axis of rotation, 43.—Arguments in support of propounding the theory, 44.

23. *Pyramidal Form of Continents.*—It requires no learned dissertation to prove that the general form of mountains is pyramidal, although there are exceptional cases of the summit presenting a flat-topped instead of a conical form. These facts are easily demonstrable, and apparent to every person who has traversed a mountainous country. But it may have escaped the notice of even careful observers, that this normal condition of land in its vertical position is also apparent in the horizontal direction of the great continental masses. Their general outline as represented on an ordinary map of

the world exhibits this geographical feature at a glance—the pyramidal bases being towards the north pole, and the apex pointing to the south pole. Africa presents its widest base in the northern hemisphere, and tapers continuously towards the south, until it reaches its apex at the Cape of Good Hope. This is especially apparent in the latter section south of the equator, where it looks like a vast mountain that has fallen into the sea. North America assumes a similar general form, although its southern pyramidal termination is continuous through Central America. South America may be considered the type of this configuration of continents, bearing a resemblance to its own peaks in the Andes, like an inconceivably great Cotopaxi or Chimborazo lying prostrate in the vast Pacific. Asia is less defined generally, but presents almost the outline of South Africa on a small scale in the territory of India, where Hindostan juts out to the south in the Indian Ocean. As a rule, therefore, it has been concluded by the most learned geographers that all the great continents assume a pyramidal form, with their bases towards the north, and tapering to an apex in a southerly direction.

24. *Ancient Views on the Subject.*—This feature of the land above the sea in its coast-outline is not confined to modern observation, for we are informed by Humboldt that "the horizontal configuration of continents in their general relations of extension, was already made the subject of intellectual contemplation by the ancient Greeks. Conjectures were advanced regarding the maximum of the extension from west to east, and Dicæarchus placed it, according to the testimony of Agathemerus, in the latitude of Rhodes, in the direction of a line passing from the pillars of Hercules to Thinè. . . . Strabo, who was probably influenced by Eratosthenes, appears to have been so firmly convinced that this parallel of 36° was the maximum of the then existing extension of the world, that he supposed it had some intimate connection with the form of the earth, and therefore places under this line the continent whose existence he

divined in the northern hemisphere between Thoria and the coasts of Thinè." These observations of the ancients go far to prove that in their researches regarding the geography of the world they were equally intelligent with modern observers; and that it was their limited knowledge of lands beyond Europe which confined their ideas.

25. *Modern Observations.*—In modern times the subject was revived, and we are informed that "the pyramidal configuration of all the southern extremities of continents belongs to the "similitudines physicæ in configuratione mundi," to which Bacon already had called attention in his 'Novum Organon,' and with which Reinhold Foster—one of Cook's companions in his second voyage of circumnavigation —connected some ingenious considerations. On looking eastward from the meridian of Teneriffe, we perceive that the southern extremities of the three continents—viz., Africa, as the extreme of the Old World, Australia, and South America—successively approach nearer the south pole. New Zealand, whose length extends fully 12° of latitude, forms an intermediate link between Australia and South America, likewise terminating in an island. It is also a remarkable circumstance that the greatest extension towards the south falls, in the old continent, under the same meridian in which the extremest projection towards the north pole is manifested. This will be perceived on comparing the Cape of Good Hope and the Agulhas Bank with the North Cape of Europe, and the peninsula of Malacca with Cape Taimura in Siberia. . . . The pyramidal terminations of the great continents are variously repeated on a smaller scale, not only in the Indian Ocean, and in the peninsulas of Arabia, Hindostan, and Malacca, but also, as was remarked by Eratosthenes and Polybius, in the Mediterranean, where these writers had ingeniously compared together the forms of the Iberian, Italian, and Hellenic peninsulas. Europe, whose area is five times smaller than that of Asia, may almost be regarded as a multifariously-articulated western peninsula of the more compact mass of the continent of Asia, the climatic

relations of the former being to those of the latter as the peninsula of Brittany is to the rest of France."*

26. *Humboldt traces the Form through all Continents.*—If we continue these researches from the configuration of peninsulas and the great continents to the whole body of the earth, we find the general principle maintained, as set forth in the theory herein advanced, not only in the coast-line above the ocean, but, as far as has been ascertained, down to the beds of all the great seas. On this point Humboldt remarks:—"One hemisphere of the earth (whether we divide the sphere through the equator or through the meridian of Teneriffe), has a much greater expansion of elevated land than the opposite one; these two vast ocean-girt tracts of land, which we term the eastern and western, or the old and new continents, present, however, conjointly with the most striking contrasts of configuration and position of their axes, some similarities of form, especially with reference to the mutual relations of their opposite coasts. In the eastern continent, the predominating direction—the position of the major axis—inclines from east to west (or, more correctly speaking, from south-west to north-east), whilst in the western continent it inclines from south to north (or rather from south-south-east to north-north-west). Both terminate to the north at a parallel coinciding with that of 70°; whilst they extend to the south in pyramidal points, having *submarine prolongations* of islands and shoals. Such, for instance, are the Archipelago of Tierra del Fuego; the Agulhas Bank, south of the Cape of Good Hope; and Tasmania, separated from the mainland of Australia by Bass Strait. Northern Asia extends to the above parallel at Cape Taimura, which, according to Krusenstern, is in lat. 78° 16'; whilst it falls below it from the mouth of the Great Tschukotschja river, eastward to Behring Strait in the eastern extremity of Asia, Cook's East Cape, which, according to Beechy, is only lat. 66° 3'. The northern shore of the new continent follows with tolerable exactness the parallel of 70°, since the lands to the

* Humboldt—'Asie Centrale.'

north and south of Barrow Strait, from Boothia Felix and Victoria Land, are merely detached islands."*

27. *His Views on the Cause of this Phenomenon.*—Seeing that there is a degree of uniformity in the configuration of the continental masses on the earth amounting to a general principle, the question arises, Have we any geological or astronomical data to account for this phenomenon? On this head Humboldt expresses his views cautiously, as follows:—"Very little can be empirically determined regarding the casual connection of the phenomena of the formation of continents, or of the analogies and contrasts presented by their configuration. All that we know regarding this subject resolves itself into this one point,—that the active cause is subterranean—that continents did not arise at once in the form they now present, but were increased by degrees by means of numerous oscillatory elevations and depressions of the soil, or were formed by the fusion of separate smaller continental masses. Their present form is therefore the result of two causes, which have exercised a consecutive action the one on the other: the first is the expression of subterranean force, whose direction we term accidental, owing to our inability to define it, from its removal beyond the sphere of our comprehension; whilst the second is derived from forces acting on the surface, amongst which volcanic eruptions, the elevation of mountains, and currents of sea-water, play the principal

28. *The Probability of its being a General Law in Nature.*—That there is some general law in nature, only secondary to the universal law of gravitation, which regulates this phenomenon, it is reasonable to conclude. Here we find that as mountains are pyramidal in their vertical elevation from the centre of gravity, so the horizontal forms of continents are pyramidal; and in treating of the configuration of the earth itself, we have endeavoured to show that there is a general tendency in its solid parts to assume that form between the poles, notwithstanding the spherical law

* Humboldt's 'Cosmos.'

which regulates its fluid and aerial envelopes. May there not be a subsidiary law regulating the planetary bodies while entering into their solidifying state, so as to consolidate the general structure upon a pyramidal principle? And may not that law be connected with the rotation of the earth upon its axis, as essential to the maintenance of its equilibrium in the ecliptic, having its equatorial plane displaced at an angle of 23° 30′, just as the conical form of the common top is essential to its spinning when it leans to one side while describing a circle? If the earth were a perfect sphere, equal in diameter at the crossing-point of every parallel of latitude and meridian of longitude, with the specific gravity of its substance uniform in ratio from its centre to its circumference, it might probably have no fixed axis of rotation. Without this guiding principle for its daily revolutions it would, perhaps, be an erratic globe rolling hither and thither on no fixed law of rotation, except in its annual course round the sun; just as a billiard-ball rolls over a table without any defined axis of rotation, yet keeping the line of momentum from the point where it was struck. It is impossible to conceive what would be the effects of such a condition if it could exist on the earth under its present state. For the sake of illustration, we may say that London might one day be within the arctic circle, next day in the tropics, and make a revolution from the north to the south celestial hemisphere in twenty-four hours. Under these circumstances, we can easily imagine that it would be no fit habitation for animals or plants. Therefore, from these indications of a pyramidal structure in the solid materials of the world, it is evident that it is in obedience to some law equivalent to that which rules the spherical form of aqueous bodies.

29. *This Form augmented by the Land below the Sea-Level.*—If this pyramidal form of continents is so apparent at the sea-level, as delineated on an ordinary map, in all probability it would be still more evident if we could ascertain correctly the general formation of the ocean-beds. This has been already alluded to in defining the altitude of the land upon

the earth, irrespective of the water, showing that the perpendicular height of its solid parts in relation to its lowest spherical proportions is double that of its coast-line elevation, if not more. Below that line the observations of hydrographers, in their laborious task of sounding the depths of seas, prove as a rule that the land gradually slopes deeper and deeper until a point is reached where declination ceases, and the water becomes shallower as the lead sounds the opposite shore; just as in a lake, a river, or a channel, should they dry up, their beds would appear as valleys between the land which formed their banks. In like manner the beds of the great oceans are merely continental valleys filled with salt water. If we could behold them drained, then should we see the pyramidal form of the continents sloping on each side to the bottom of the valleys of the Atlantic, Pacific, and Indian Oceans, with their tapering forms trending as far as the south pole, and there forming a general apex for the pyramidal configuration of the earth—or, to speak more correctly and cautiously, an approximation of a general character towards that form.

30. *Probable Pyramidal Form of the Moon.*—It may be said that such a theory is contrary to the laws of the universe, where nothing but spherical bodies roll through the boundless realms of space. "Behold the sun, moon, and planets with their satellites." It may be said, "These are all perfect spheres lighting up the heavens by day and night, and the earth would be an exception to the universal rule, if it assumed even the smallest approach to a pyramidal form." Not so. Recent observers of the moon have discovered that the central part of her disc bulges out beyond the spherical outline, but which is never seen in profile in consequence of the time of her orbital motion being equal to that of her axial revolution. It is supposed that the half of the moon visible to us is not a spherical hemisphere, but elongated; and if the other half is flattened like the earth in proportion, the shape of her satellite would approximate to that of an egg. Those who have seen the very beautiful photographs of the moon by Warren

de la Rue may distinguish this phenomenon, where the foreshortening of the disc appears to culminate in an apex, different from that of a perfect globe. It is no part of this work to venture upon the question of that interesting discovery further than this casual reference, and in support of the theory that there are important deviations from sphericity among the planets and their satellites, which require further research by astronomers before the phenomenon can be thoroughly demonstrated.

31. *Sinking of the Land.*—In connection with the raising of continental masses as the chief modifying power in altering the normal condition of the earth, we must not overlook the opposite force of gravitation, which has caused the land to sink below its primary level. This phenomenon has been observed from the earliest historic period on the land above the level of the sea, where it has been submerged, and on inland territory which has suddenly sunk by some internal collapse. As a general principle of geology, the upheaval of land at one place would cause a corresponding depression at another; and this no doubt occurred at the depths of the sea when the continental masses were raised. How far the level of the primitive ocean was altered by these convulsions has not been ascertained; but if the average depths of all the seas be twenty times greater than the average elevation of the continents and islands, then it must have decreased in level, and also in quantity, as the mineral constituents were deposited in the form of strata. During the periods when the greatest activity prevailed in the volcanic forces of the earth towards the exterior of the northern hemisphere, there was evidently a corresponding action in the forces of gravitation. The result of these two great contending forces was the upheaval of the continents of Europe, Asia, Africa, and North America on the one hand; and the sinking of the lower crust of the earth, on the other hand, at the regions forming the beds of the Atlantic, Pacific, and Indian Oceans. Thus, while the volcanic forces acted as a *positive* power in hurling the earth from its equilibrium in the ecliptic by a preponderance of land up-

heaved above the sea-level in the north, the forces of gravitation exercised a *negative* influence towards the same result in diminishing its density in the south by the sinking of its ocean-beds.

32. *Darwin's Observations in the Pacific Ocean.*—Here, then, we have a general principle established regarding the structure of the earth in its solid parts, as well as in the liquid and aeriform constituents, that whatever modification its surface undergoes in elevation, there is at some place a corresponding depression. These phenomena are exemplified on an extensive scale in the Pacific Ocean. According to Darwin, the groups of coral islands in the equatorial and northern divisions of that hemisphere of water are slowly sinking, which he proves by the coral insects being always busy at work raising their walls to the surface of the sea around the crater cones of the submarine peaks, which at a past geological epoch rose above the level of the ocean. This would indicate a general subsidence of the ocean-bed in these latitudes, which has led to the theory of some French *savans*, that "Oceania," as that region is named on their charts, is the remains of an extinct continent that formerly united Asia with North America. Although that hypothesis gives support to our theory, inasmuch as the preponderance of land in the north hemisphere might have been infinitely greater than at present, still we are not disposed to indorse these views to their full extent. Suffice it that there are data to prove the sinking of a large area of land at the bottom of the north and equatorial sections of the Pacific. Now, in the South Pacific we have a corresponding gradual elevation of the land, in the island-continent of Australia, which all the learned geographers and others who have visited its shores pronounce to be slowly upheaving at so many feet in a century.

33. *Subsidence and Elevation of Land in Sweden and Finland.*—If, then, we have evidence of a sinking of the land in the south hemisphere during the periods of its elevation in the north, according to a general law of equivalents in the geological theory of forces, we must conclude that a contrary

effect took place when these forces were reversed in their hemispheres of action. When the continent of South America was upheaved by consecutive volcanic forces, doubtless corresponding depressions in the land occurred at other parts of the earth's crust, but, for obvious reasons, human researches cannot investigate to any great extent the submerged evidence of this phenomenon. We may safely conclude, however, that as the sinking of the land in the south hemisphere reached its greatest depression during the elevation of the north continents, the equivalent depressions to South American elevations would occur in the north hemisphere. That such phenomena have been in operation in Europe is abundantly evident from the observations of geologists where it is visible in its effects at the present day. Certainly these are comparatively small in area; nevertheless they are sufficient to indicate that there was a sinking of the land in the Polar Sea and North Atlantic during the upheaval of the South American continent. On this subject Humboldt has the following remarks:—"According to the views generally adopted by geognosists in the present day, and which are supported by the observation of a series of well-attested facts, no less than by analogy with the most important volcanic phenomena, it would appear that the elevation of continents is actual and not merely apparent or owing to the configuration of the upper surface of the sea. The merit of having advanced this view belongs to Leopold von Buch, who first made his opinions known to the scientific world in the narrative of his memorable 'Travels through Norway and Sweden in 1806-7.' Whilst the whole coast of Sweden and Finland, from Sölvitzborg on the limits of Northern Scania, experiences a gradual rise of four feet in a century, the southern part of Sweden is, according to Neilson, undergoing a simultaneous depression." * Sir Charles Lyell also informs us that, from the observations of the Danish *savans*, it is evident that a large portion of the coast of Greenland has been gradually sinking during the last four centuries. "An-

* Humboldt's 'Cosmos.'

cient buildings on low rocky islands and on the shore of the mainland have been gradually submerged, and experience has taught the aboriginal Greenlander never to build his hut near the water's edge. The Moravian settlers have been obliged more than once to move inland the poles upon which their large boats were set, and the old poles still remain beneath the water as silent witnesses of the change." *

34. *Geological Subsidence in the North Atlantic Basin.*—From the remarkable analogy that exists in the structure of the land in North America and Europe, together with the similarity between the extinct fauna and flora of the two continents, there are data for concluding that they were united during the tropical era in northern latitudes; so that the Atlantic telegraph cables are now reposing on land at a perpendicular depth of two to three miles from the level of the sea, which once was elevated above its surface, diversified by hills, valleys, plains, and table-lands, covered with a dense vegetation, and inhabited by multitudes of strange reptiles, quadrupeds, and birds. It requires no elaborate argument to arrive at this conclusion. Suppose the land which now constitutes the bed of the North Atlantic for upwards of 2000 miles from east to west, and forty degrees of latitude from north to south, fell from its high altitude in obedience to the eternal laws of gravitation, its subsidence was probably produced by an equivalent in accumulated volcanic forces to that which upheaved the continent of South America.

35. *Humboldt on the Causes that change the Figure of Continents.*—"The phenomena to which we would here direct attention remind us of the instability of the present order of things, and of the changes to which the outlines and configuration of continents are still subject at long intervals of time. That which may scarcely be perceptible in one generation, accumulates in periods of time whose duration is revealed to us by the movement of remote heavenly bodies. The eastern coast of the Scandinavian peninsula has probably

* Lyell's 'Principles of Geology.'

risen about 320 feet in the space of 8000 years; and in 12,000 years, if the movements be regular, parts of the bottom of the sea which lie nearest the shores, and are in the present day covered by nearly fifty fathoms of water, will come to the surface and constitute dry land. But what are such intervals of time compared to the length of the geognostic periods revealed to us in the stratified series of formations, and in the world of extinct and varying organisms? We have hitherto only considered the phenomena of elevations, but the analogies of observed facts lead us with equal justice to assume the possibility of the depression of whole tracts of land. The mean elevation of the non-mountainous parts of France amounts to less than 480 feet. It would not, therefore, require any long period of time, compared with the old geognostic periods in which such great changes were brought about in the interior of the earth, to effect the permanent submersion of the north-western part of Europe, and induce essential alterations in its littoral relations. . . . The depression and elevation of the solid or fluid parts of the earth are the causes of all the changes which occur in the configuration of continents." *

36. *Probable Changes that occur below the Sea-Level.*—If these observations on the laws of volcanic forces affecting the land above the level of the sea are applicable to the configuration of continents, how much greater in degree is their application to the form of the land below that level, where the great bulk of the earth's crust is hid from view? If we had the same facilities of observing the ocean-beds as we have of the continental areas, in all probability the elevations and subsidence of vast tracts of land would be seen of which we at present know little or nothing. The investigations of Mr Darwin into the formation of coral-reefs and islands furnish satisfactory evidence that there is now, and probably has been for ages, a gradual subsidence in the bed of the Pacific Ocean, where the islands of Polynesia rear their volcanic peaks from a depth rivalling in elevation the peaks of the

* Humboldt's 'Cosmos.'

Andes above the present sea-level. The equivalent in elevation for this subsidence is on the mainland of Australia, where the absence of very high mountains, or great contortion of stratified rocks, leads geologists to the conclusion that the volcanic forces which upheaved that region have in all probability been comparatively feebler than in other regions of an equal superficial area.

37. *Antipodal Equivalents of Elevation and Depression in the Earth's Crust.*—From the general principles of subterranean forces, as exemplified in the foregoing investigations and generalisation of facts by the most eminent authorities, it will be seen that throughout the structure of the earth's crust, below the sea as well as above its level, there is evidence of an equivalent in depression for every point of elevation. Moreover, as far as they can be ascertained, these indications of subsidence are not far removed from lands that are upheaving. From this is deduced the theory that the volcanic forces are comparatively limited in area, and not deep-seated in the framework of the earth. This may be the case at the present day, but it does not follow that they have been superficial for all time. On the contrary, if we extend our observations from these local phenomena to the leading geological evidences of the first subsidence of ocean-beds and elevation of continental masses, there are data for concluding that the primeval volcanic forces emanated from the central internal regions of our planet. If we refer to a terrestrial globe, and observe the antipodes of the centres of elevated lands in the north hemisphere, we find them represented in the south hemisphere by deep seas, where the ocean-bed in some cases is one-fourth greater in depth below, than the highest mountain-chains are above, the level of the sea. Besides the downward force of gravitation, this arises from the enormous superincumbent pressure of the ocean, by which means has been produced the greater average depth below of 20,000 feet, to 1000 feet of elevation above, the sea-level. Be this as it may, we have the geographical evidence before us, that, as a rule, the antipodes of the great continents are

seas. This is remarkably exemplified by those portions of the land between middle latitudes and the circumpolar regions in the north hemisphere having their equivalent at the south antipodes in a deep circumnavigable ocean. Moreover, the north polar sea depression has an equivalent of land elevation in a probable south polar continent, if we are to accept the opinions of our most advanced geographers, who base their views upon the recent voyages of discovery by Captain Ross and others.

38. *Controversy regarding the Equipoise of the Continents.*—Before the circumnavigation of the globe was accomplished through the voyages of discovery by Captain Cook and other renowned navigators in the south hemisphere, there were great discussions amongst the learned men of Europe concerning the proportions of land and water in the world as affecting its diurnal as well as annual rotation. "For upwards of a century before the actual configuration of Australia was ascertained, the most distinguished European astronomers, geographers, and navigators entertained the theory that there must be a continent in the southern hemisphere equal in extent to those of Asia and Europe in the northern. They argued that, in order to preserve the equilibrium of the globe, the land of the southern division must extend through the tropical and temperate zones into the antarctic circle, in the same manner and in corresponding meridians to what was then either known or supposed, on good grounds, to extend from the equator into the arctic regions. They presumed that the world could not revolve equally upon its axis unless there was an area of land above the ocean, between the south pole and the equator, equal to that in the northern hemisphere. A glance at the terrestrial globe will show to what a small extent this theory has been carried out by facts. Australia will be seen to counterbalance scarcely the area of Europe; while the vast Asiatic continent has no other equivalent than the boundless ocean."*

39. *Proofs that the Equipoise of the Earth is not main-*

* 'Our Australian Colonies.' By Samuel Mossman.

tained.—Notwithstanding the failure in the solution of this geographical problem, to the credit of these inquirers be it said, that they observed the anomaly of the preponderance of land in the north hemisphere, which required to be accounted for in the south, as affecting the equilibrium and rotation of the terraqueous globe. So far, their conclusions were based upon scientific data, that the counterpoise of the north hemisphere could not otherwise be maintained than by the existence of an equivalent in land above the sea at the antipodes in the south hemisphere, if the equatorial plane had been parallel with the plane of the earth's orbit round the sun. Such, however, not being the case—as the earth's axis is inclined to that plane in an angle of 66° 32′ 36″, whence the equator is inclined to the ecliptic in an angle of 23° 27′ 24″—we contend that this deflection solves the geographical problem; that the equilibrium of the earth's diurnal revolution is not maintained, otherwise it would revolve daily in an equatorial plane uniform with its annual course, without presenting the phenomena of the seasons. On the other hand, according to our theory, the disturbance in its equiponderance may have been caused by the upheaval of the greater mass of land in the north hemisphere over what exists in the south—especially those continental masses above the level of the sea forming the table-lands of Asia and North America, with the Himalayas and other mountain-systems, which added to the centrifugal force of rotation in first giving momentum to this obliquity of the earth's axis. As already shown, it is a well-known geographical fact that nearly three-fourths of the earth's surface are covered with water. But this does not imply that water forms any great proportion in the ponderosity of the terraqueous globe. On the contrary, its actual weight, we have seen, is infinitesimally small compared to that of its solid contents. Notwithstanding the apparently boundless superficies of the Pacific, Atlantic, and Indian Oceans, and their almost unfathomable depths, yet they are only great lakes lying in the valleys of the land. The bed of the sea, we have also seen, consists of

table-lands, valleys, mountains, and plains, the counterpart of those geographical features we see above its level. And if we consider that the mean specific gravity of the earth is to that of water as $5\frac{1}{2}$ to 1, it will be seen how little the sea enters into the scale in maintaining the equilibrium of the world. Hence the south hemisphere, where the seas prevail, is still further reduced in balancing the north hemisphere by reason of the lighter material that enters into its surface composition, equivalent to a loss of four times the weight of the entire ocean.

40. *Origin of Maps on East and West Hemispherical Projections.*—If we look at an ordinary map of the world in hemispheres, this disparity is easily observable; but it would strike the observer more forcibly if seen on a terrestrial globe divided in half at the equatorial line. Geographers and map-makers have confined their delineations of the world to the arbitrary division of the eastern and western hemispheres; consequently, the public eye has been so educated to this projection that it fails at first sight to comprehend the vast difference between the geographical aspect of the north and south hemispheres. It may not be generally known that this division of the earth is a relic of the Spanish and Portuguese discoveries in the sixteenth century. On these being sanctioned by Pope Alexander VI., he marked out a line traversing the poles which divided the terrestrial globe—giving to the former all lands discovered west of that line of demarcation, and to the latter the eastern territories. Without cavilling with that division, it would be well that modern atlases contained a map of the world on the south and north hemispherical projection, such as will be found in this volume, in order to render the outlines of the unequal distribution of land and water familiar to the eye.

41. *Figure of the Earth shaped more like a Lemon than an Orange.*—The configuration of the earth is set down by astronomers to be that of an *oblate spheroid* of revolution—that is, a sphere flattened at the poles, the polar axis being to the equatorial diameter in the ratio of 305 to 306. In

familiar language it is compared to the shape of an orange. This popular definition applies admirably to the general figure of the north hemisphere, where the polar sea is almost encircled by land, rising into mountain-ranges and table-lands that render the depression at the north pole well marked in its profile; while the vast bulk of Europe, Asia, North Africa, and North America swell into the rind of the orange to the middle belt. If we cross the equator, however, this shape is not maintained; and, to follow out the comparison, the world in its southern division assumes something of a lemon shape. Sir James Ross, in his voyage of discovery towards the south pole, came upon elevated land trending to an unknown extent in that direction; and this, with the previous observations of Captain Cook and Kerguelen, furnishes data for concluding that there is an extensive mountain region in the centre of the south polar latitudes. Some geographers even go far to prove that there exists a mountainous continent equal in area to the north polar sea. Be that as it may, the latitudes outside this unexplored region are known to be encircled by the open sea, thereby reversing the configuration of the earth in the antarctic to what it is in the arctic regions.

42. *The Form and Movements of the Earth like a Top spinning.*—In computing the polar diameter of the earth at 7898 English miles, as compared with the equatorial diameter of 7925, astronomers show a difference of 27 miles. Without disputing that calculation, it is not illogical to conclude that the depression at the north pole is considerably greater than at the south, inasmuch as the water is immediately affected by the diurnal revolution of the globe where the land is not. At all events, the flattening at the north pole has not its equivalent in the south. Moreover, if we take the land as the ruling body, by virtue of its ponderosity, in the rotation of the earth, this diversity of contour is more apparent. Suppose the world emptied of its seas, the bed of the Arctic Ocean would present a still greater depression at the north pole, while those of the Atlantic, Indian, and Pacific Oceans

in the south would give the antarctic regions something of a tapering form. In that case, the solid framework of the earth, as the rotating power which sustains its diurnal revolution, may be considered an *oblato-oblong spheroid*—or, to use a familiar comparison, *top-shaped*. And that well-known toy, which has beguiled our boyhood's hours by its rotation, may show to the popular mind a familiar example of the obliquity of the ecliptic, when the top leans to one side while spinning, yet describing a circle in its course while kept in motion—the former illustrating diurnal revolution, and the latter annual rotation.

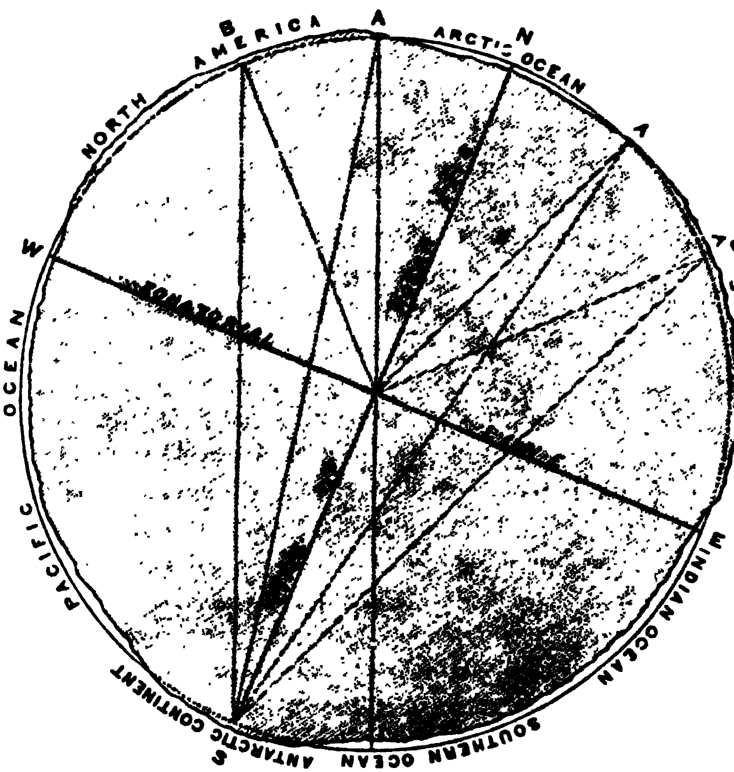


Fig. 2.

SECTION of the EARTH.—Illustrating the great Elevations and Depressions of its External Solid Parts above and below the Level of the Sea.

43. *Diagram illustrating Theory of Unequal Poise in the Earth's Axis of Rotation.*—The annexed diagram, exhibiting

a section of the earth, will serve to illustrate the drift of our theory regarding the great continental elevations and oceanic depressions of its solid parts above and below the level of the sea. Of course the proportions of the external crust are purposely enlarged, as compared with the earth's diameter, in order to make the theory more easily understood. There are three great points delineated: 1st, the continent of Asia, having the Pacific Ocean for its antipodes; 2d, the North American continent, with its antipodes in the Indian Ocean; and, 3d, the depression of the Arctic Ocean, in all probability having an antipodal elevation in an antarctic continent. The line of the polar axis, it will be seen, terminates in the centre of the north polar sea on the one hand, and at a supposed culminating mountain in the south polar continent on the other. The present inclination of the polar axis to the earth's orbit is shown by the lines A, and the probable extension of that inclination, before the diminution of the obliquity, is suggested by the lines B. If we take into consideration the fact, that the termination of these lines in the north hemisphere touches a line of circumference along the most elevated regions, we can understand how the centrifugal motion of the earth is accelerated at these angles, having its true apex of revolution at the south pole. When we consider, also, how delicately our planet is poised in space, and the incalculable power exercised by its subterranean forces in affecting its equilibrium, it cannot be deemed unphilosophical to consider the preponderance of land in the northern hemisphere, and the central volcanic action which elevated these regions, as the primary motive power in the earlier epochs of the earth's geological history that caused the inclination of its axis, thereby displacing the equatorial plane from the plane of its orbit, and producing the vicissitudes of the seasons that did not previously exist.

44. *Argument in support of advancing the Theory.* — It may be said that the conclusions arrived at here are not supported by geological evidence, or if they are, it is in a degree so small that they do not warrant such stupendous deduc-

tions. In reply we advance the logical argument, that it is not the abundance of testimony at the outset that substantiates a principle always; for there are many truths now established which sprang from apparently very feeble propositions. No study has proved that in a more forcible manner than geology itself, where we have seen the formerly-despised hypothesis that fossils were organic remains, become the basis of the whole science—connecting extinct with living species of plants and animals, and opening up for human contemplation a field of knowledge only second to the study of astronomy itself. If our theory be viewed in that light, as simply suggesting a new process of generalisation from existing data, there can be nothing rash in advocating it. It does not start a new system of classifying sedimentary strata or crystalline rocks; or infringe upon the doctrines of geology as established on existing causes and effects. All that we have endeavoured to show is additional evidence in the earth itself, not merely considered in its minor parts but as a grand whole, that from geological causes have sprung astronomical effects which further tend to exalt the science. From the structure of our own planet the study is now extending to a knowledge of the physical condition of her satellite and other members of the planetary sphere; so that, as observers increase their knowledge by improved instruments, we may have in time a geology of the solar system. As a step in that direction we have treated the structure of the earth in these brief geological passages more as a unit of that system than in its terrestrial magnitude. This naturally brings us to the consideration of our subject from its astronomical point of view, and to see what light the planets throw upon our theory of the origin of the seasons.

CHAPTER III.

EXTINCT TROPICAL EPOCH IN EUROPE.

Problem of the earth's axis being inclined not geometrically solved, § 45.—Eratosthenes the first to calculate the distance of the tropics, 46.—Astronomical theory of axial inclination designated "obliquity of the ecliptic," 47.—Assumed limits to tropical oscillation of obliquity, 48.—Advantages of geological research into vestiges of extinct epochs, 49.—Fossil remains of extinct animals a popular study, 50.—London Zoological Gardens a restoration of extinct British fauna, 51.—Kew Botanical Gardens a restoration of extinct British flora, 52.—Humboldt's theory of the tropical epochs in Europe, 53.—Theory of a perpetual equinox having existed, 54.—Evidence of a perpetual equinox in the planet Jupiter, 55.—Domes of elevation and basins of depression in the earth's crust, 56.—Lyell's theory of "uniformity of change," past and present, 57.—Fossil evidence of an extended tropical region, 58.—Lyell's theory not sufficient to solve the question, 59.—Combined with our hypothesis, capable of giving a better solution to the problem, 60.

45. *Problem of the Earth's Axis being inclined not geometrically solved.*—At the outset of this part of our inquiry we meet with the astronomical problem, whether the inclination of the earth's axis is caused by the equatorial plane having moved away from the plane of the orbit, or *vice versâ.* In other words, has the earth in its annual movement round the sun diverged from the line of its diurnal motion, or has the latter departed from the path of the former? This question is not yet determined to the satisfaction of astronomers, consequently it is still a moot point among them, as we shall presently see. Meanwhile, we may remark that, according to our theory, the question would be more appropriately put as between the axis of revolution

instead of the planes of rotation. This manner of putting the problem does not alter its value in the least, while it has the advantage of placing the question more clearly in a popular point of view, which is aimed at in this essay. Here are two lines, as shown in the diagram subjoined—one representing the *axis of annual rotation*, and the other the *axis of diurnal revolution*—separated from each other on the circumference of the earth by about twenty-three degrees and a half of latitude. If the planetary perturbations advanced by astronomers be the sole disturbing influences, then it is probable that the axis of the earth's orbit has been deflected from its axis of revolution. On the other hand, if our theory be the correct one, the axis of daily revolution receded from that of yearly rotation, as it is seen in the diagram, where the latter is shown by its perpendicular line, and the line of the former crossing it at an angle of 23½° in both hemispheres. Viewed in this manner, the distance between the tropics resulting from the difference between the orbital and equatorial planes is only a solar effect of a terrestrial cause. At the same time, it must be observed, we may infer from the principles of both theories, that the present inclination of the earth's polar axis is a departure from a normal condition when it probably coincided with the axis of its orbit.

46. *Eratosthenes the first to calculate the Distance of the Tropics.*—Having thus endeavoured to show theoretically that the unequal hemispherical proportions of the earth, produced by its internal forces, originated the inclination of its axis, we now proceed to ascertain the exact angle of that inclination and its attendant phenomena in the tropics. In this part of our inquiry we combine the observations of geologists and astronomers in elucidating the problem, and giving a clear conception of the past condition of the seasons as compared with the present. Although mankind from the earliest ages studied their recurrence within the more northern latitudes of the temperate zone, yet it was on the border of the Tropic of Cancer that the angle of the earth's axial

inclination was first ascertained by observing its limit in Africa, where the perpendicular rays of the sun at the summer solstice fall, as shown on the annexed diagram. The observer was Eratosthenes, an ancient philosopher, born 276 years before the Christian era, at Syene, the most southern

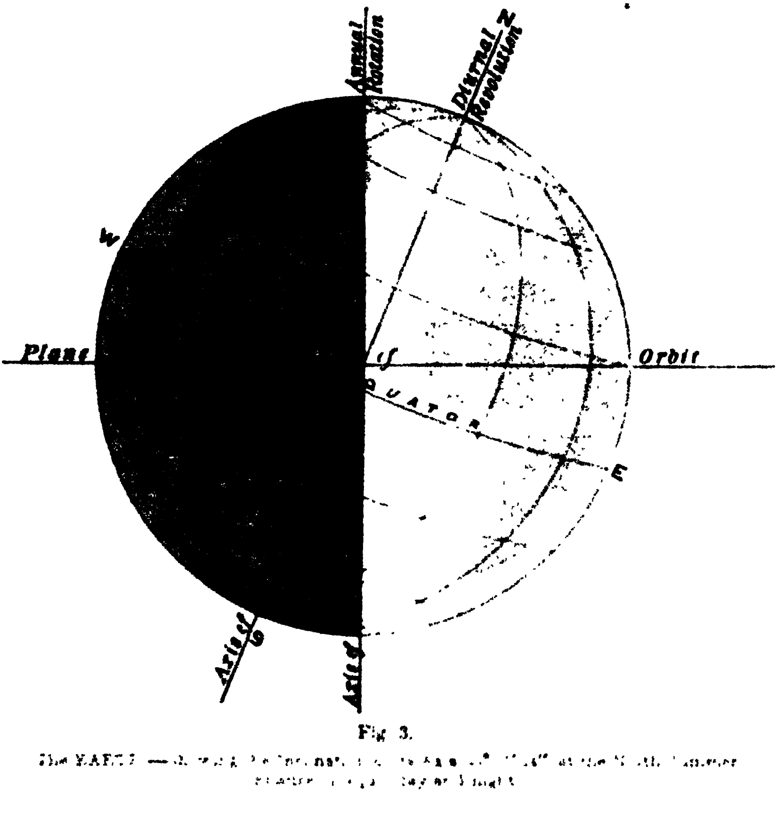


Fig. 3.

[illegible]

of the cities of ancient Egypt. That city was known to be situated exactly under the Tropic of Cancer; for at the summer solstice the gnomon of the sun-dial had no shadow, and the sun's rays illumined the bottom of a deep well within its precincts. From this circumstance it is supposed that he applied his ingenuity to the invention of an instrument for calculating the distance between the tropics and other astronomical phenomena, known as an armillary sphere. By means of an instrument of this kind, he observed the distance

to be as 11 to 83 of the whole circumference of a great circle; a ratio equivalent to 47° 42′ 39″, half of which gives 23° 51′ 19.5″ for the latitude of the tropics in his day. This is a very important observation, as the distance is now reduced to 23° 27′ 24.2″, showing a considerable diminution in the inclination of the earth's axis; or, as astronomers designate the phenomena, "in the diminution of the obliquity of the ecliptic as indicated by theory." *

47. *Astronomical Theory of Axial Inclination designated "Obliquity of the Ecliptic."*—If it be a demonstrable fact, which learned geometers affirm it is, that the obliquity of the ecliptic has been diminishing during historical periods, we have here the most substantial data to infer that it must have been greater in pre-historic ages. It is true that their computations are confined to a very limited diminution of the obliquity; "and theory has shown that the cause of the displacement is the action of the planets, particularly of Jupiter and Venus, on the earth, by virtue of which the plane of the earth's orbit is drawn nearer to the planes of the orbits of these two planets. This, however, though by far the most considerable, is not the sole cause of the phenomenon; for theory also shows that a slight motion of the plane of the equator is produced by the attraction of the sun and moon, but so very minute that its effects will only become appreciable after a long series of ages." † This brief description embodies the generally-received doctrine of astronomers as regards the inclination of the earth's axis, which, on their own showing, is based upon an abstruse theory regarding the perturbations of certain members of the planetary sphere. It is entirely transmundane, and ignores the earth as having had any influence in bringing about this most important part of its condition, affecting as it does the destiny of all created things upon its surface. On the other hand, there is abundant evidence in geology to show that in its earlier epochs a much greater obliquity of the ecliptic existed than anything even hinted at by astronomers. And

* Art. "Astronomy," 'Encyclopædia Britannica.' † Ibid.

as it is a question at what angle of displacement the diminution continually going on from year to year will cease, so is it a problem to be solved as to what was the extreme obliquity in former ages—or, in other words, up to what latitude did the tropical declination of the sun reach during the summer solstice in the north hemisphere at its greatest primary angle?

48. *Assumed Limits to Tropical Oscillation of Obliquity.*—At the present day we find that the maximum declination of the sun, which marks the outer lines of the tropical zones, is computed at 23° 27' 24.2"; a century back it was 23° 28' 15"; and if we accept the calculations of Eratosthenes twenty centuries ago, it was 23° 51' 19.5". This diminution of 23' 55.3", in such a space of time as two thousand years, is small, and may well satisfy timid minds that any vital changes in the seasons need not be apprehended in their day, or for many generations to come. And so far, therefore, might this part of our subject be summarily dismissed, as it has been by the astronomers, who state, rather confidently, we think, and upon indeterminate grounds, as already mentioned, "that the planes of the ecliptic and equator, which have been approaching to each other during the last 2000 years, will, in the course of some thousands of years more, begin to recede." Also, that "the gradual diminution of the obliquity of the ecliptic might lead us to suppose that a time will ultimately arrive when that plane will coincide with the equator, and the earth be deprived, in consequence, of the agreeable vicissitudes of the seasons. But the theory of universal gravitation, which has revealed the cause of the diminution, has also shown that there are certain limits which the angle of the two planes can never exceed, and between which it must continue for ever to oscillate." *

49. *Advantages of Geological Research into Vestiges of Extinct Epochs.*—These arguments may be very consolatory to the agricultural mind that dreads any vital change in the seasons; but they shut out all investigation regarding the former conditions of our planet, when these vicis-

* Art. "Astronomy," 'Encyclopædia Britannica.'

situdes were not in existence, or in their rudimentary stages. It is very different, however, if we trace this phenomenon to causes that are coeval with the solid structure of our planet, of which the islands, continents, and mountain-chains are the vestiges of the inconceivable internal forces through which those comparatively placid changes in the temperate regions originated. By adopting the geological mode of investigation, additional light may be thrown upon the extinct organic world, whose fossil remains are found of tropical types in the rocks of the north temperate zone and the arctic regions. Hitherto the science of geology has unfolded the wondrous history of the earth, from its primeval epoch down to recent ages, furnishing a panoramic view of the progress of its inorganic matter, and the development of the vegetable and animal kingdoms. As a concentration of the physical sciences applied to natural phenomena, in order to elucidate that history, the results have been most satisfactory; and every day fresh views of igneous and aqueous agencies, extinct fauna and flora, and the antiquity of man, are being added to the accumulating facts. Still, it must be admitted that the chain of events is incomplete. There are gaps in the sequence of epochs that remain to be filled up, notwithstanding the indefatigable labours of deep-thinking and far-searching geologists and naturalists. Moreover, throughout the data on which the various periods are founded—notwithstanding the wondrous restoration of disjointed fossil remains into their living semblance—there is a want of vitality in the pictures, which might be added if geological investigation was turned more in the direction we propose going—leading, as it were, to the condition of the sea and the atmosphere, as well as of the land, during past geological periods. By this method of research we may obtain correct glimpses of the extinct landscapes and sea-views which once prevailed in the latitudes of Europe; and be able to account more satisfactorily for the existence of the extinct species of animals that flourished under a tropical climate in the British Isles—or even in Greenland, where a frigid clime now prevails.

On this interesting and important branch of our inquiry Humboldt observes:—"The cold regions of the earth contain, deposited in sedimentary strata, the products of tropical climates; thus, in the coal-formations, we find the trunks of palms standing upright amid coniferæ, tree-ferns, goniatites, and fishes having rhomboidal osseous scales; in the Jura limestone, colossal skeletons of crocodiles, plesiosauri, planulites, and stems of the cycadeæ; . . . . and, lastly, in transported soils, and in certain caves, the bones of elephants, hyenas, and lions. An intimate acquaintance with the physical phenomena of the universe leads us to regard the products of warm latitudes that are thus found in a fossil condition in northern regions not merely as incentives to barren curiosity, but as subjects awakening deep reflection, and opening new sources of study."

50. *Fossil Organic Remains and Living Animals a Popular Study.*—It is in the spirit recommended by the earnest-thinking author of 'Cosmos' that we venture to suggest a new mode of inquiry into this open field of investigation. Yet it is sometimes necessary, in the midst of profound argument, to enliven the natural curiosity of the popular mind by familiar illustrations, in order that the general reader may take more interest in the question. For instance, when persons visit the Zoological Gardens in London to see the caged monarchs of tropical regions, how few think, or even know, that at one period in the geognostic history of the British Isles, monster mammals and reptiles of similar types, bulk, and form to these, were the "lords of creation" on the very ground whereon they stand, or in the surrounding country, but under very different climatic and terrestrial conditions! How few know that the ancient progenitors of these huge creatures—the elephant, rhinoceros, hippopotamus, lion, tiger, and hyena, with crocodiles and other ferocious animals—roamed through the tropical forests and inhabited the waters of Great Britain! and how few know that remains of such animals are found in the very London clay which forms the substratum under the soil on which the Gardens are

laid out! Such, however, is the fact, which has been indisputably proved to the most sceptical mind by the researches of Sir Charles Lyell, Professor Owen, and a host of other men of science. Looking, therefore, at the assemblage of animals in that unrivalled zoological collection from this point of view, the visitor sees nothing new that has not existed on the spot before, during the tropical epoch that nurtured similar gigantic forms. All the difference is, that man has brought them at immense expense, trouble, and danger, from distant regions, and, to protect himself from their destructive nature, he has caged them behind strong iron bars; whereas their extinct prototypes moved about in unrestrained liberty—in all probability before the human race existed.

51. *London Zoological Gardens a Restoration of Extinct Fauna.*—How strange, yet true, that at one period there was a great lake all over the land where London now is situated, and that amphibious monsters wallowed on its muddy shores, just as we see the rhinoceros and hippopotamus in their ponds within the enclosure of the gardens! It might even be that when the rhinoceros emerges from his bath, turning his horned muzzle to some child's hand for cake, covered with claggy particles rooted from his watery bed, the same clay was stirred up by the indigenous hippopotami of Britain during its tropical era. How strange, also, that among the giant trees of the primeval forest, and the dense jungle which then existed on the margin of that lake, the lion devoured his prey, awakening the echoes around with his roar, probably within hail of the very locality where the growl may be heard of his African descendant at feeding time! And stranger still, the vestiges of that bygone epoch prove that the kangaroo which has been brought from Australia to hop about an enclosure fifteen thousand miles from its native land, is only a living representative of pouched animals that once grazed on the pasture-lands of England! Moreover, turtles at that period laid their eggs on Primrose Hill—which rose above this extinct lake like a small gravelly isle—after they had been swimming over the site of eht

Mansion House, where others of their kind, brought from the West Indies, a distance of four thousand miles, are now boiled down into aldermanic soup! And more wonderful still, frogs larger than turtle croaked in the jungles of our isle, with a noise probably greater than the lion's roar! But it is not our purpose to enter minutely into the zoology of this epoch, as it has been done sufficiently by eminent geologists. Suffice it to add, that among the remains "A crocodile has been described by Dr Buckland from Sheppy and Bognor; and an alligator has been announced by Mr Searles Wood at Hordwell. Thus it would appear that the eocene reptilian fauna of Britain was of a tropical character, even as the mammalian and invertebrate faunas of that period, and as the plants, appeared to have been." *

52. *Kew Botanical Gardens a Restoration of Extinct British Flora.*—In like manner—following up our inquiries in this familiar way—visitors to the Kew Gardens, on entering the palm-houses there, heated to an uncomfortable degree, are breathing an atmosphere of the same temperature, and see vegetation of a similar character, to that which prevailed during that epoch. As to the amount of vegetation which flourished and decayed on the land in these ages, we have evidence, in the extensive coal-measures of England and Scotland, that it must have been of a more luxuriant and tropical character than exists at present; while we find living types of that flora in the tropics of Australia. But as this branch of our subject will be more fully entered upon in the part treating of "the air," we shall reserve further details until then. Meanwhile, let it be understood that there are geological data from which it is impossible to infer anything else than that a tropical climate, with its animals and plants, existed once in European latitudes, the same in condition and intensity as now exists within the tropics of Asia, Africa, America, and Australasia, at the level of the sea. This being the case, it only remains to consider the question that naturally arises, Under what circumstances did this intensely hot

* Professor Owen in 'Reports of the British Association.'

period originate? As usual, many theories have been propounded which have evoked learned discussions on this point, but without any satisfactory conclusion being attained; and it is just possible that our theory may be thrown into the limbo of rejected scientific speculations. Nevertheless we shall do our best, without fear of ridicule, to lay it before the public, especially as some of the theories discarded have been advanced by those who possessed a higher reputation for scientific research than we can lay claim to.

53. *Humboldt's Theory of the Tropical Epoch in Europe.*—Without entering into the numerous speculations and discussions on this point, we shall quote first from Humboldt's 'Cosmos' a passage wherein the great physical philosopher hints at the possibility of this tropical era in the present cold regions of the earth having arisen from an excess of internal heat in the planet itself, more than from the external heat of the sun, as follows:—"I apply the term *volcanic*, in the widest sense of the word, to every action exercised by the interior of a planet on its external crust. The surface of the globe and that of the moon manifest traces of this action, which, in the former at least, has varied during the course of ages. Those who are ignorant of the fact that the internal heat of the earth increases so rapidly with the increase of depth, that granite is in a state of fusion about twenty or thirty geographical miles below the surface, cannot have a clear conception of the causes, and the simultaneous occurrence of volcanic eruptions at places widely removed from one another, or of the extent and intersection of *circles of commotion* in earthquakes, and equality of chemical composition observed in thermal springs during a long course of years. The quantity of heat peculiar to a planet is, however, a matter of such importance—being the result of its primitive condensation, and varying according to the nature and duration of the radiation—that the study of this subject may throw some degree of light on the history of the atmosphere, and the distribution of the organic bodies imbedded in the solid crust of the earth. This study enables us to under-

stand how a tropical temperature, independent of latitude (that is, of the distance from the poles), may have been produced by deep fissures remaining open, and exhaling heat from the interior of the globe, at a period when the earth's crust was still furrowed and rent, and only in a state of semi-solidification; and a primordial condition is thus revealed to us, in which the temperature of the atmosphere, and climates generally, were owing rather to a liberation of caloric and of different gaseous emanations (that is to say, rather to the energetic reaction of the interior on the exterior), than to the position of the earth with respect to the central body, the sun." This view of Humboldt's may be considered the extreme of geological views accounting for the tropical era of Europe; nevertheless it shows the opinion such an eminent authority had concerning the "furrowed and rent" condition of the world in its pristine state, when he infers a degree of volcanic action and disturbance of its equilibrium that might not only be sufficient to account for the obliquity of the ecliptic by volcanic forces, but almost to cause the equator and the poles to change places in relation to the earth's orbit.

54. *Theory of a Perpetual Equinox having once existed.*—According to Lyell: "At first it was imagined that the earth's axis had been for ages perpendicular to the plane of the ecliptic, so that there was a perpetual equinox and uniformity of the seasons throughout the year; that the planet enjoyed this 'paradisiacal' state until the era of the great flood; but in that catastrophe, whether by the shock of a comet or some other convulsion, it lost its equal poise, and hence the obliquity of its axis, and with that the varied seasons of the temperate zone, and the long nights and days of the polar circles." At the period when this and other theories of the earth were propounded, it was the custom to call in astronomical and miraculous influences to account for certain terrestrial phenomena, of which many have been since proved to emanate from causes within the sphere of our planet itself. This arose in a great measure from ignorance of the science of

geology, as at present established, even in its rudimentary principles. In its place an arrangement existed of fanciful theories called generally the *Cosmogony of the World*, comprised of little else than a conglomeration of astronomical and Scriptural dogmas. It was not until the beginning of the present century that correct views concerning the structure of the earth were entertained, and our knowledge regarding its ancient development is daily extending. Even "within the memory of the present generation the science of geology has made immense progress. Aided not only by the higher branches of physics, but by recent discoveries in mineralogy and chemistry, in botany, zoology, and comparative anatomy, it has extracted from the archives of the interior of the earth, records of former conditions of our planet, and deciphered documents that were a sealed book to our ancestors. It extends its researches into regions more vast and remote than come within the scope of any other physical science except astronomy, of which it has been emphatically termed the sister science." *

55. *Evidence of a Perpetual Equinox in the Planet Jupiter.*—Notwithstanding the progress of theoretical astronomy during the past century, the practical knowledge of the physical constitution of planetary bodies was still in its infancy from the want of sufficiently powerful instruments to examine and compare their structure. During the present century great strides have been made in the construction and magnitude of telescopes and other astronomical instruments, especially the gigantic telescope of Lord Rosse, which magnifies the lunar disc so that a space of a few hundred yards square may be discernible to the observer. These instruments have revealed to us the fact that every planet and satellite belonging to the solar system, and even the sun himself, has an obliquity of the axis, and that not two of the former present the same degree of displacement between their orbits and equatorial planes, while they range at angles of inclination from 3° to 75°. Into this part of our subject we shall

* Art. "Geology," 'Imperial Dictionary.' By John Ogilvie.

enter more fully in the next section, treating of the astronomical phenomena of the seasons. Meanwhile, let us remind the reader that the cosmogonist who propounded the theory mentioned by Lyell, of the earth's axis having been probably at one period perpendicular to the plane of the ecliptic, might have supported his hypothesis astronomically by referring to the planet Jupiter as at present enjoying within a few degrees this "paradisiacal" state of its seasons—if such it may be considered where almost no variation reigns during its perpetual equinox. And if he had been acquainted with the principles of geology known at the present day, he might have advanced a theory of subterranean forces to account for the equal poise of the north and south hemispheres being lost, instead of an imaginary cataclysm or collision with a comet. So far, therefore, this theory, which is considered to be exploded by the arguments of astronomers, may be found in time to have been well conceived, though erroneously carried out.

56. *Domes of Elevation and Basins of Depression in the Earth's Crust.*—Now that the conjectures of cosmogonists are exploded, and the theories of alternate violence and repose modified by the researches of geologists, there is no necessity for resuscitating these opinions that have now been long buried. Nevertheless, should there be evidence to incline us towards a belief in the subterranean forces of our planet having been at earlier epochs *greater in degree* than in later eras, we should not discard the theory because it apparently assimilates with exploded conjectures. For example, the expansion of the rocky matter forming the igneous formations of the earth's crust by heat, and its subsequent contraction by refrigeration, are among the best-established principles of geology. We have evidence that on many elevated regions there are spots where, in cooling, the rocks have shrunk so as to cause deep ravines, and generally to contract the area of the original molten mass. From this it is inferred that as the refrigeration proceeded of the primitive crystalline rocks on which subsequent formations were de-

posited, "domes of elevation" were formed, with orifices through which the molten rocks were erupted, gradually forming the great mountain-chains and solitary peaks, until they cooled and solidified into permanent structures. On the other hand, where the plastic rock lay under the superincumbent pressure of the ocean, it subsided, in proportion to its elevation elsewhere, into "basins of depression." Thus we have a principle of expansion or swelling of the earth's crust that must have been more active at earlier than later periods of its formation, inasmuch as with the cooling of the rocks the rents for these subterranean forces became gradually closed up. It is evident, therefore, that the movements of the earth internally must have been at one time greater in degree than another, simply because the movable mass of matter was greater; and it is not rash or unphilosophical to conclude that such internal movements affected its external revolutions while so delicately poised in space until it lost its polar equilibrium.

57. *Lyell's Theory of "Uniformity of Change," Past and Present.*—At this stage of our inquiry we meet again with the arguments of Sir Charles Lyell in support of his theory of "uniformity of change" in reference to the living creation, subterranean forces, and sedimentary deposition. This theory implies that the tropical, temperate, and frigid zones, as they now exist, have been perpetually the same in latitude, or at all events unchanged from the primary epochs* of geological time to the present day. In support of this hypothesis it is advanced that if, by a different distribution of the land above the level of the sea without enlarging or contracting its area, the continents and islands were disposed within the polar regions on the one hand, or the tropical regions on the other, extremes of heat and cold would be produced in the climates of the globe. Upon this basis the theory of uniformity of change in the climate of Europe is founded, from its extinct tropical heat to its present temperate seasons, by reason of the upheaval and subsidence of immense tracts of land—evidence being given where vestiges of these subterranean

movements have occurred in modern history. Without entering into the elaborate details of this complex theory, we give the following passage, which briefly describes its purport:—"It appears that when the oldest or eocene tertiary deposits were formed, a warm temperature pervaded the European seas and land. Shells of the genus nautilus, and other forms characteristic of tropical latitudes; fossil reptiles, such as the crocodile, turtle, and tortoise; plants, such as palms, cocoanuts, the screw pine, the custard-apple, and the acacia - all lead to this conclusion. This flora and fauna were followed by those of the miocene formation, in which indications of a southern but less tropical climate are detected. Finally, the pliocene deposits, which come next in succession, exhibit in their organic remains a much nearer approach to the state of things now prevailing in corresponding latitudes. It was towards the close of this period that the seas of the northern hemisphere became more and more filled with floating icebergs, often charged with erratic blocks, so that the waters and the atmosphere were chilled by the melting ice, and an arctic fauna enabled for a time to invade the temperate latitudes of both North America and Europe. The extinction of a considerable number of land quadrupeds and aquatic mollusca was gradually brought about by the increasing severity of the cold; but many species survived this revolution in climate, either by their capacity of living under a variety of conditions, or by migrating for a time to more southern lands and seas. At length, by modifications in the physical geography of the northern regions, and the cessation of floating ice on the eastern side of the Atlantic, the cold was moderated, and a milder climate ensued, such as we now enjoy in Europe."

58. *Fossil Evidence of a widely-extended Tropical Region.*—Tracing back through the secondary formation, and still older strata, for fossils proving the change of climate in Europe, Lyell proceeds as follows:—"A great interval of time appears to have elapsed between the formation of the secondary strata, which constitute the principal portion of the ele-

vated land in Europe, and the origin of the eocene deposits. If we examine the rocks from the New Red Sandstone to the Chalk inclusive, we find many distinct assemblages of fossils entombed in them, all of unknown species, and many of them referable to genera and families now most abundant between the tropics. Among the most remarkable are reptiles of gigantic size, some of them herbivorous, others carnivorous, and far exceeding in size any now known even in the torrid zone. The genera are for the most part extinct, but some of them, as the crocodile and monitor, have still representatives in the warmer parts of the earth. Coral-reefs also were evidently numerous in the seas of the same periods, and composed of species belonging to genera now characteristic of a tropical climate. The number of very large chambered shells also leads us to infer an elevated temperature; and the associated fossil plants, although imperfectly known, tend to the same conclusion, the cycadeæ constituting the most numerous family. But it is from the more ancient coal-deposits that the most extraordinary evidence has been supplied in proof of the former existence of an extremely uniform, moist, warm, and equable climate in those latitudes which are now the colder, and, in regard to temperature, the most variable, regions of the globe. . . . The flora of the coal appears to indicate a high temperature in the air; while the fossils of the contemporaneous mountain-limestone, comprising abundance of lamelliform corals, large-chambered cephalopods, and crinoidia, naturally lead us to infer a great warmth in the waters of the northern sea of the carboniferous period. So, also, in regard to strata older than the coal; they contain in high northern latitudes mountain masses of corals which must have lived and grown on the spot, and large-chambered univalves, such as orthocerata, which indicate, even in regions bordering on the arctic circle, the former prevalence of an elevated temperature. The heat and humidity of the air, and the uniformity of the climate, appear to have been most remarkable when some of the oldest fossiliferous strata were formed. The approximation to a climate similar

to that now enjoyed in these latitudes does not commence till the era of the formations termed tertiary; and while the different tertiary rocks were deposited in succession, the temperature seems to have been still further lowered, and to have continued to diminish even after the appearance upon the earth of a considerable number of the existing species —the cold reaching its maximum of intensity in European latitudes during the glacial epoch, or the epoch immediately antecedent to that in which all the species now contemporary with man were in being."*

59. *Lyell's Theory not sufficient to solve the Question.*—To account for these geological evidences of extraordinary changes of temperature, the data and arguments adduced are voluminous, and based upon the theory of uniformity of change in the land and sea as observable since the historical era. Having the highest regard for the principles of geology as propounded by Sir Charles Lyell, and the research shown by him in treating of its details, we are not disposed to reject his arguments absolutely. At the same time we must admit that, after carefully weighing all the evidence, it is not sufficient to convince us that it affords a complete solution of the problem. There appears to be some link wanting in the chain of testimony—some leading phenomenon connected with the structure of the earth that has either been overlooked or has not yet been discovered. May we not find that missing link in the theory herein advanced, that the tropical zone extended beyond its present latitudes during these epochs, when it reached a maximum probably twice its present limits, and afterwards gradually diminished? This hypothesis is not incompatible with Lyell's theory, provided the subterranean movements be considered to have been of greater magnitude at primary periods than subsequently or in the present era, acquiring their maximum of force during the epochs of the secondary formation in the northern hemisphere, and gradually diminishing during the tertiary epochs, when their great-

* Lyell's 'Principles of Geology.'

est power was transferred to the southern hemisphere. The admission of such a principle would divest Lyell's theory of its complexity, and render the study of fossil, vegetable, and animal remains more satisfactory to the inquiring student of geology, who is at present perplexed with the conflicting evidence of the past and present history of the organic world. Moreover, it might tend to show the astronomical observer that the physical influences which produced the variations of the seasons have been of a simpler character than the intricate perturbations attributed to the origin of these phenomena.

60. *Combined with our Hypothesis, capable of giving a better Solution.*—We have said that the theory of Lyell is not sufficient to convince us of such a vital change in the climate of Europe as geological testimony indicates, but that, with the addition of our hypothesis of a widely-extended tropical zone, it would be more satisfactory. This is especially the case with the section which endeavours to show that the diminution of the earth's obliquity of axis by reactionary subterranean movement has been slow and uniform. Let us once believe in the changes of climate resulting from the contraction of the tropical zone, after reaching a maximum double its present latitude, and the epochs of the eocene, miocene, and pliocene formations, followed by the glacial period, may be more satisfactorily accounted for than before. It is perfectly consistent with it that the geological changes during those periods were going on with all the uniformity he asserts, while the astronomical changes we suggest stamp the fossil records with the seal of truth. On the one hand, our theory does not support the old hypothesis of sudden universal catastrophes overwhelming animated nature, or violent changes of climate; and, on the other hand, it eschews the extravagant periods of geological time, computed by geologists from the deposition of sedimentary strata. Steering a middle course, we shall further endeavour to show that, although no cataclysm happened to the earth in its earlier

ages, there are astronomical data for concluding that it reached an extreme phase in its annual rotation; also that, though the epochs of its history may not be sempiternal, we have astronomical time sufficient to calculate the lapse of vast periods since a tropical sun shone upon the lands of Northern Europe.

CHAPTER IV.

EXTINCT TROPICAL EPOCH IN EUROPE.—*Continued.*

Sir John Herschel's astronomical views on the subject, § 61.—His suggestions of a former greater degree of solar heat, 62.—M. Poisson's theory of great stellar heat in space, 63.—Problem of tropical epoch in Europe unsolved by astronomical theories, 64.—Difference between a planet's axial and orbital inclination, 65.—Precession of the equinoxes and its physical cause, 66.—Distinction between the phenomena of precession and obliquity, 67. Secondary causes that produce the seasons well known, 68.—Secular diminution in the inclination of the earth's axis, 69.—Average diminution in a century, 70.—Tropical epoch in Europe accounted for by an extended torrid zone, 71.—Probable period when the earth had no inclination of axis, 72. The planet Jupiter an example of the earth at this period, 73.—Temperate latitudes at this period a perpetual spring, 74.—Action of internal forces during earliest geological epochs, 75.—Primary quiescent condition of the earth broken up, 76.—Internal action continued through ages increasing the tropical zone, 77.—Argument in favour of its having been formerly widely extended, 78.—Its probable extension to 45° of latitude, 79.—Computation of geological time by stratified rocks, 80.—Computation by extinction of species, 81.—Croll's estimate of glacial period by precession of the equinoxes, 82.—Rate of diminution of obliquity a basis for calculating geological time, 83.—Not to be considered arbitrary, but suggestive, in the formula of computation, 84.

61. *Sir John Herschel's Astronomical View of the subject.*—The remarkable changes of climate in Europe that have occurred within geological periods of time have attracted the notice of modern astronomers. We are told that "Sir John Herschel has lately inquired whether there are any astronomical causes which may offer a possible explanation of the difference between the actual climates of the earth's surface and those which formerly appear to have prevailed. He has

entered upon this subject, he says, impressed with the magnificence of that view of geological revolutions which regards them rather as regular and necessary effects of great and general causes, than as resulting from a series of convulsions and catastrophes regulated by no laws and reducible to no fixed principles. Geometers, he adds, have demonstrated the absolute invariability of the mean distance of the earth from the sun, whence it would at first seem to follow that the mean annual supply of light and heat derived from that luminary would be alike invariable. But a closer consideration of the subject will show that this would not be a legitimate conclusion, but that, on the contrary, the *mean* amount of solar radiation is dependent on the eccentricity of the earth's orbit, and therefore liable to variation. Now, the eccentricity of the orbit, he continues, is actually diminishing, and has been so for ages beyond the records of history. In consequence, the ellipse is in a state of approach to a circle, and the annual average of solar heat radiated to the earth is actually on the *decrease*. So far this is in accordance with geological evidence, which indicates a general refrigeration of climate; but the question remains, Whether the amount of diminution which the eccentricity may have undergone can be supposed sufficient to account for any sensible refrigeration?"* On this point M. Arago was of opinion that the mean amount of solar radiation can never be materially affected by irregularities in the motion of the earth.

62. *His suggestion of a former greater Solar Heat.*—Sir John Herschel ventures upon "another astronomical suggestion respecting the possible causes of secular variations in the terrestrial climates which deserves notice. It has long been known that certain stars are liable to great and periodical fluctuations in splendour, and Sir J. Herschel has lately ascertained that a large and brilliant star, called *Alpha Orionis*, sustained, in the course of six weeks, a loss of nearly half its light. 'This phenomenon,' he remarks, 'cannot fail to awaken attention and revive those speculations which were first put

* Lyell's 'Principles of Geology.'

forth by my father, Sir W. Herschel, respecting the possibility of a change in the lustre of our sun itself. If there really be a community of nature between the sun and fixed stars, every proof that we obtain of the extensive prevalence of such periodical changes in those remote bodies adds to the probability of finding something of the kind nearer home.' Referring, then, to the possible bearing of such facts on ancient revolutions in terrestrial climates, he says that 'it is a matter of observed fact, that many stars *have* undergone, in past ages, within the records of astronomical history, very extensive changes in apparent lustre without a change of distance adequate to produce such an effect. If our sun were even *intrinsically* much brighter than at present, the mean temperature of the surface of our globe would, of course, be proportionally greater. I speak now not of periodical but of secular changes. But the argument is complicated with the consideration of the possibly imperfect transparency of the celestial spaces, and with the cause of that imperfect transparency, which may be due to material non-luminous particles diffused irregularly in patches analogous to nebulæ, but of greater extent—to *cosmical clouds*, in short—of whose existence we have some indication in the singular and apparently capricious phenomena of temporary stars, and perhaps in the recent extraordinary sudden increase and hardly less sudden diminution of η *Argus*.'" *

63. *M. Poisson's Theory of great Stellar Heat in Space.*—"Another astronomical hypothesis respecting the possible cause of secular variations in climate has been proposed by a distinguished mathematician and philosopher, M. Poisson. He begins by assuming—1st, That the sun and our planetary system are not stationary, but carried onward by a movement through space; 2dly, That every point in space receives heat as well as light from innumerable stars surrounding it on all sides, so that if a right line of indefinite length be produced in any direction from such a point, it must encounter a star either visible or invisible to us; 3dly, He then goes on to

* Proceedings Roy. Astronom. Soc., cited by Lyell.

assume that the different regions of space, which, in the course of *millions* of years, are traversed by our system, must be of very unequal temperature, inasmuch as some of them must receive a greater, others a less, quantity of radiant heat from the great stellary inclosure. If the earth, he continues, or any other large body, pass from a hotter to a colder region, it would not readily lose in the second all the heat which it has imbibed in the first region, but retain a temperature increasing downwards from the surface, as in the actual condition of our planet." *

64. *Problem of Tropical Epoch in Europe unsolved by Astronomical Theories.*—These and other speculative conjectures of astronomers to account for the ancient tropical heat that pervaded the atmosphere and ocean in our temperate latitudes, it is not necessary to go minutely into, or to cite the arguments of Lyell and other geologists in their refutation. Suffice it to state, that none of them have been accepted as in any way solving the problem, not even by astronomers, so that they do not take rank in the principles of theoretical astronomy. It would appear that, in searching for some cosmical principle in the boundless regions of space as the cause of these phenomena, astronomers have overlooked the more probable solution to the question we have put forward, in a well-established principle of our terrestrial sphere itself—namely, the diminution of the obliquity of the ecliptic causing the refrigeration of climate, from which we infer that there was formerly an increase of obliquity creating a general tropical climate over the present temperate regions.

65. *Difference between the Inclination of a Planet's Axis and its Orbit.*—Not only do the speculative theories of astronomers fail to account for these extraordinary climatic changes, but we are of opinion that the causes they assign for the origin of the seasons, from which all existing varieties of climate have sprung, are not sufficient to convince us of their terrestrial influence so far. These are the perturbations which the most influential planets—Venus, Mars, Jupiter,

* Lyell's 'Principles of Geology.'

and Saturn—are alleged to have on the earth's orbit, so as to separate its plane from the equatorial plane, and cause the obliquity of the ecliptic. As to the secondary causes which produce the summer and winter solstices, and the vernal and autumnal equinoxes, these are proved to mathematical demonstration; but it is otherwise with the primary causes to which we allude. While there are differences between the planes of the planetary orbits which may be produced by their perturbations on each other's movements round the sun, still these do not coincide with the various inclinations of their axes. For example, the inclination of the axis of Mars is 28° 51′, while that of his orbit is only 1° 51′, and these inclinations in Venus are respectively 49° 58′ and 3° 23′; showing that the perturbations of the planets, however much they may affect the eccentricity and inclination of each other's orbits, cannot be said to influence the angles of their axes of rotation. This point of our subject we shall more particularly refer to when treating of the planets individually.

66. *Precession of the Equinoxes and its Physical Cause.*—Besides the perturbations of the planets on the earth's orbit, there are attractive influences of the sun and moon that affect its revolution, which are named and briefly described as follows:—"*The precession of the equinoxes* is a slow retrograde movement of the equinoctial points—viz., from east to west, or contrary to the order of the signs. The equinoctial points do not retain the same position in the heavens, but have a slow retrograde motion at the rate of about 50¼″ in a year, or about a degree in 72 years—the equator moving on the ecliptic, while the ecliptic remains nearly coincident with the same fixed stars. This phenomenon is called the precession of the equinoxes, because it makes the equinoxes succeed each other in less time than they would otherwise do. In consequence of the precession of the equinoxes, the longitudes and right ascensions of the heavenly bodies are continually increasing, and owing to the motion of the equator, which occasions that precession, their declinations also are altered. The precession of the equinoxes was discovered by Hipparchus

a century and a half before the Christian era, though it is alleged that the astronomers of India had discovered it long before. At that time the point of the autumnal equinox was about six degrees to the eastward of the star called *Spica Virginis.* In 1750—that is, about nineteen hundred years after—this point was observed to be about 26° 21′ westward of that star. Hence it appears that the equinoctial points will make an entire revolution in about 25,745 years." *

67. *Distinction between the Phenomena of Precession and Obliquity.*—The physical cause of this phenomenon, as distinguished from that of the obliquity of the ecliptic, is accounted for in the following manner:—"The diminution of the obliquity of the ecliptic arises from the displacement of the ecliptic itself; the precession of the equinoxes is, on the contrary, occasioned by the continual displacement of the plane of the terrestrial equator. This displacement results from the combined action of the sun and moon (for the influence of the planets amounts only to a fraction of a second, and is consequently scarcely sensible) on the mass of protuberant matter accumulated about the earth's equator, or the matter which forms the excess of the terrestrial spheroid above its inscribed sphere. The attracting force of the sun and moon on this shell of matter may be resolved into two—one parallel to the plane of the equator, the other perpendicular to it. The tendency of this last force is to diminish the angle which the plane of the equator makes with that of the ecliptic; and if the earth had no motion of rotation, it would soon cause the two planes to coincide." † In this demonstration of a phenomenon connected with the equinoxes of the seasons, we find astronomers acknowledging that the excess of matter at the equator affects the earth's rotation on that plane. May we not, then, as philosophically conclude that *the mass of protuberant matter* in the north as compared with the south hemisphere influences the inclination of the axis?

68. *Secondary Causes that produce the Seasons well*

* 'Imperial Dictionary,' art. "Precession."

† 'Encyclopædia Britannica,' art. "Astronomy."

known.—Of the secondary causes that produce the vicissitudes of the seasons astronomers furnish abundance of demonstrable facts, with which, we presume, even the most superficial reader is acquainted; while the scientific reader knows that their calculations of the sun's declination, and other astronomical phenomena in the ephemeris, are the most profound computations in geometry. With deep learning and untiring zeal they have elucidated the various phases which the diurnal revolution of the earth assumes in its annual rotation, passing "from the vicissitudes of the day to the seasons of the year," as the second fundamental object of astronomy. These phases are laid down with mathematical accuracy. Diagrams are executed to illustrate the position of the earth in the solar system at the advent of spring, summer, autumn, and winter; and the exact days when the solstices and equinoxes occur are registered in almanacs for the guidance of the public. Abstruse calculations are made to define the positions of the sun, moon, and stars for the use of navigators in determining their latitude and longitude on every day of the year. These and other practical demonstrations of the phenomena resulting from the inclination of the earth's axis are familiar to most people, yet few have thought of inquiring into the origin of the secondary causes producing these effects. Notwithstanding the many learned disquisitions to which the obliquity of the ecliptic, as the immediate cause of the seasons, has given rise, still the primary origin of that phenomenon, as stated before, remains to be satisfactorily accounted for. Astronomers have not yet determined mathematically whether it results from the plane of the earth's orbit being displaced from the equatorial plane, or *vice versâ*;—in less technical language, whether the line of annual rotation round the sun has separated from that of daily revolution, or the contrary. According to our geological theory of this displacement being the effect of forces within the earth itself, we would infer that the plane of the equator has separated from the plane of the orbit—or ecliptic, as it is denominated, in consequence of its path being that of

eclipses. Thus it would appear that astronomers hitherto have been content to point out the secondary causes and effects of the phenomenon without inquiring too deeply into the primary causes that produced planetary obliquity of axis; and so satisfied apparently are they with these results, that it seems unnecessary to inquire any further into the question. If we placed implicit faith in these conclusions, we might well lay down our pen and abandon the subject of our discourse; while, under the circumstances, it may be deemed presumptuous on our part to look for a terrestrial solution to the problem. But we feel satisfied that some useful result may follow this astro-geological method of inquiry; and in the end we may find that as the earth benefits in its animal and vegetable life from the glorious changes in the seasons, so is there evidence to infer that these have sprung from the internal action of the great globe itself.

69. *Secular Diminution in the Inclination of the Earth's Axis.*—The astronomical question arises here as to whether the inclination of the earth's axis or the obliquity of the ecliptic is the same now as at earlier periods in ordinary history? On this point observations have been collected extending over the space of two thousand years, showing that there is a small but gradual diminution of the phenomenon. The earliest observation recorded, we have stated, is that by Eratosthenes, a famous Greek philosopher, who flourished in the second century before the Christian era. He calculated the sun's declination at 23° 51′ 19.5″, which was afterwards confirmed by Hipparchus and Ptolemy. In 1860 it was computed at 23° 27′ 24.2″, showing a diminution within the intervening period of 23′ 55.3″. Of course, allowance must be made for the rudeness of the instruments used by the ancients as compared with those to be found in modern observatories. "The ancient observers were not, indeed, possessed of the means of determining an element of this sort with great precision; but as all the observations recorded in history agree in making the obliquity greater in former times than it is now, the probability is almost infinite that the angle

formed by the planes of the equator and the ecliptic has really diminished; for, had the difference of values assigned to it arisen solely from errors of observation, they would have been in excess and defect indifferently, instead of being, as they are, uniformly in excess." *

70. *Average Diminution in a Century.*—Taking the average diminution of the foregoing extremes of observation, the result amounts to about 70" in a century. But the ancient observations being too uncertain, they have been rejected; and, comparing those only which have been made since the time of Bradley in 1755, the secular diminution has been fixed at 45.7" in a century. Whether it is accelerated or retarded at different periods has not been ascertained; but there can be no doubt that its diminution is still going on, and, with the delicate and minutely-graduated astronomical instruments of the day, may be calculated annually. This fact involves the vital point of the whole subject under review. The diminution of the obliquity, however gradual, however slow, proves that at one period it was on the increase, and that it may eventually lead to a period when it will reach the line of perpetual equinox, and the earth, in consequence, be deprived of the agreeable vicissitudes of the seasons. In order to show that such a consummation is not in harmony with the theory of universal gravitation, astronomers consider that they find in the disturbing influences of other planets the true cause of this diminution, to which they state there are certain limits beyond which it cannot proceed, and will for ever oscillate between them. "Geometers," we have before stated, "have not yet ventured to assign the precise extent of those limits, but their existence is certain; and the planes of the ecliptic and equator, which have been approaching to each other during the last 2000 years, will, in the course of some thousands of years more, begin to recede." †

71. *Tropical Epoch in Europe accounted for by an extended Torrid Zone.*—Assuming that the earth has been driven into its obliquity of axis by its own internal forces, it does not

* Art. "Astronomy," 'Encyclopædia Britannica.' † Ibid.

follow that this diminution will cease in a few thousand or in fifty thousand years, when it will again commence increasing the displacement of its planes. On the contrary, it is more probable, if not a certainty, that the diminution will continue until the equatorial plane shall coincide with the plane of the ecliptic—when there shall be no seasons, and day and night will be of equal length throughout the year all over the world, from the poles to the equator. Reasoning upon this basis, it is not illogical to conclude that in the early epochs of the earth's formation, when the great bulk of the igneous rocks were upheaved with tremendous force, shaking the earth from its centre to its circumference, the inclination of the earth's axis, or the obliquity of the ecliptic, was many degrees greater than it is at present: a period when the sun's rays fell with almost tropical intensity upon the verge of the arctic circle for perhaps six months during the year, thereby counteracting the frigidity of the polar winter, and rendering the circumpolar regions habitable by animals only found at the present day within the tropics. This would account for the existence of the tropical epoch in Europe—a question which has baffled the researches of so many inquirers.

72. *Probable Period when the Earth had no Inclination of Axis.*—To comprehend this condition of the world in its pristine state, we must suppose that it was externally a sphere of water, or rather an oblate spheroid, being flattened at the poles in its liquid or plastic condition, by reason of its centrifugal force, in rotation, throwing the elastic matter towards the equator from the axis of revolution. At this period, also, there was little or no obliquity of the earth's axis, and hence there were no seasons, while day and night would be equal in every latitude from the poles to the equator. In proof that there are data for these inferences we have only to refer to the conclusions arrived at by astronomers regarding the physical constitution of the planet Jupiter, which may be considered at present as being in a condition similar to that of the earth during the epoch we refer to. "The inclination of his equator to his orbit is only 3° 5′ 30″, so that the variations of

his seasons must be almost insensible."* Thus it is not unphilosophical to conclude that at one period, before the land appeared above the surface of the ocean, there was little or no displacement of the ecliptic, and the vicissitudes of the seasons were not yet in existence. It will be seen, however, that the Almighty Designer of the universe had not yet created the animated beings who were to enjoy their fruits, or the vegetation that was to fructify under their influence. The sea was everywhere, and the land was hidden from the genial influence of the sun by the superincumbent body of water.

73. *The Planet Jupiter an example of the Earth's condition at this period.*—When, however, the pent-up volcanic forces below the bed of the sea began to work towards the surface, the ocean was driven hither and thither to make way for the new order of things. At first the upheaved land, in domes of elevation, reached only a short distance towards the sea-level; but, by the accumulated forces, it rose sufficiently to receive the light and heat of the sun penetrating the shallow waters, warming them to such a degree that marine plants and zoophytes sprung from the organic principle that pervades matter, and propagates under certain laws which are as inevitable as the law of gravitation. At this period there was no ice at the poles, in consequence of the sun shining constantly within the present polar circles, as it does during the equinoxes in March and September, when day and night are equal in length. Then, as a preponderance of matter heavier than the water was driven towards the north hemisphere, the equilibrium of the globe began to totter. Still, the primary blasts from the mines of incandescent rock within the profound depths of the earth only gave a *lurch*, as it were, to the axis of rotation, and for ages it may not have exceeded the obliquity of Jupiter's ecliptic—which is not sufficient, as far as we know, to *ice his poles.*

74. *Temperate Latitudes at this period a perpetual Spring.*—At this period, likewise, those latitudes within what we

* Art. "Astronomy," 'Encyclopædia Britannica.'

now denominate the temperate zones would receive a greater degree of heat from the central luminary in consequence of there being no severe winter to lower the temperature; and it is just possible that, on the first lands that rose above the ocean in the present latitudes of Europe, the plants that grew were of a tropical character, or what may be called semi-tropical, such as the araucarias of the carboniferous formation. Be this as it may, we can scarcely consider the heat to have been of such intensity and permanence as to account for the existence of the leviathan creatures that inhabited the lakes, rivers, and forests of Great Britain, the remains of which have been already referred to. It may be suggested that the atmosphere at that period was so much denser than at present, that while the tropics were subject to a temperature of twice the average heat now ascertained, the temperate zones glowed under a tropical heat, while the arctic and antarctic circles enjoyed a temperate clime. These points will be fully considered under the third division of our subject when treating of the atmosphere.

75. *Action of internal Forces during the earliest Geological Epochs.*—Meanwhile we shall resume the consideration of the internal forces, and their effect on the land in driving the earth from its equilibrium. These once having obtained a weak point in the shell that enclosed their energies, battered at that point until a breach was made, not merely raising "domes of trachyte and cones of basalt" through isolated apertures, but splitting up the crust hardened by incandescent matter into long lines of eruption, creating the bases of those vast mountain-chains which are the most wonderful phenomena of the earth's solid surface. Evidently one weak fissure begat another; or when one crack was choked up with solid matter it cooled and another broke out, generally parallel with its predecessor, or with lesser fissures at right angles; and thus we have the vast congeries of mountain-systems on the globe, of which those of Asia are the most remarkable, and among the most ancient in their formation. Not only did these volcanic forces within our planet, by some

irrepressible law, seek the surface and concentrate their energies on the weakest parts, but, as already frequently observed, they were, for immense periods of time, directed almost entirely to the latitudes and longitudes north of the equator; while those in the southern half were comparatively free from their influence. And we shall see that it was not until the first northern fissures were closed that the unexpended volcanic agency found vent for its surplus matter by the stupendous latitudinal rents through which the Cordilleras of the Andes were upheaved in regions south of the equator. In this manner we contend that the first operations of nature commenced in the alembic of our planet, which has resulted not only in diversifying its surface with mountain and valley, river and lake, but in producing those perturbations in its movements whence arise the glory of the seasons.

76. *Primary quiescent condition broken up.*—Let us now consider the world in that pristine state, when the silicious and other deposits from the ocean became hardened into a crust on which the waters reposed, lying upon an even bed, and without a rock to break their surface, like a crystal sphere gleaming in the realms of space. Let us further consider the extent of the subterranean heat that first solidified these deposits, thereby confining the incandescent rocky matter within a shell, which increased its volcanic force as the strata became thicker, condensing the caloric by superincumbent pressure, until the internal forces reacted on the external, and the earth swelled and heaved below the sea in a struggle between fire and water for supremacy on its surface. Let us then conceive the tremendous revolution that inaugurated the new order of things which followed in the constitution of our planet—the breaking up of its previous quiescent state, and the disruption of its aqueous uniformity by convulsions rending the framework of the world. And let us bear in mind that these mighty concussions, these universal earthquakes, this inconceivable volcanic action, and the consequent upheaval of vast masses of solidifying rock, were in the beginning directed chiefly towards the north

hemisphere almost exclusively, raising it above the level of the sea without equivalents in elevation within the south hemisphere.

77. *Internal Action continues through Ages increasing the Tropical Zone.*—Now let us imagine the globe poised in space, delicately balanced on its axis of rotation, yet revolving with violent activity in its diurnal and annual course, suddenly shaken by the outburst of the first igneous formation, and we can conceive how it was driven from its equilibrium, at first only a degree or so, but increasingly by the impetus of repeated concussions and upheavals, until the plane of the equator differed considerably from that of the earth's orbit. From that time forth day and night lost the monotony of duration which previously characterised them, and the annual rotation varied with the declination of the sun reaching the solstices in each hemisphere. This went on for ages, but with probably accelerated speed on the upheaval of some new mountain-system in Asia, Africa, Europe, or North America, so that in time the inclination of the earth's axis reached the angle at which we now find it, with the vicissitudes of spring, summer, autumn, and winter, to vary the aspect of the revolving year. But, although the northern continents and islands were then established above the sea-level—not as they are now, yet approximate in area and elevation—nature had scarcely time to clothe their naked rocks with vegetation, or people the shallow waters with highly-organised creatures. Hence the seasons at this epoch passed over the temperate zone without fostering and renewing that vegetable and animal life which marks their course at present. No vestiges appear among the fossil remains unfolded by geological research of a temperate fauna and flora having existed before the tropical era to which we now direct our attention.

78. *Argument in favour of an extended Tropical Zone.*—Having traced the effect of volcanic force in disturbing the equilibrium of the world so as to cause it by continuous action to reach an obliquity of twenty-three and a-half de-

grees from its pristine position, it is not illogical to conclude that it went considerably beyond that angle. As we have already seen, according to astronomical data, it has exceeded to a fractional extent its present tropical limits within the range of human history; and why should it be regarded as improbable that the displacement was not greater in the proportion which geological epochs bear to historical eras? Time given, there is nothing unscientific in concluding that at one period the obliquity of the ecliptic was twice as great as we find it now, when a tropical sun shone in the zenith upon the extinct fauna and flora of Europe. We have seen by the incontestible evidence of fossil remains, interpreted by the light of science, under the investigations of acute, learned men, that plants and animals analogous to those inhabiting the torrid zone in bygone periods existed even as far north as the British Isles. Does this not amply warrant the conclusion that the continually-increasing angle of obliquity reached a limit bordering on the latitudes of our own shores? Can we not suppose, without any violation even of the doctrines of astronomy, that the same forces which caused the displacement of the two planes to the angle they now subtend, may have increased it to a still greater obliquity, until it was checked by some counteracting force of a character similar to that which originally set it in motion?

79. *Probable Extension of the Extinct Tropics to 45° of Latitude.*—Humboldt informs us that, "in the Jura limestone, colossal skeletons of crocodiles, plesiosauri, planulites, and stems of the cycadeæ exist;" all creatures and plants of an essentially tropical nature. If we take the middle latitude of the Jura Mountains on the map, we find it at 47° N. This is precisely double the present declination of the sun in the Tropic of Cancer, which intersects the great desert of Sahara in Africa. Now, as we know that alligators and other tropical monsters are found in the Nile considerably to the north of that line, we are not justified in concluding that the ancient extent of the tropical zone we contend for reached to the latitude of the Jura Mountains. On the other hand, having

seen that there are abundance of tropical fossils in the rocks and deposits of England and Scotland, we may fairly take these latitudes as analogous, during the European tropical epoch, to the African shores of the Mediterranean at present. For the sake of illustration, therefore, let us strike the limit at 45°, and we find at once a solution of this mysterious problem in the physical history of the world. Here no gratuitous theory interposes to upset astronomical doctrines on the one hand, or geological data on the other. No direct overthrow of the axis of rotation to the equatorial plane or *vice versâ* need be assumed; or a state where the earth's crust had fissures and yawning gaps, of such extent and depth that the subterranean heat and gaseous elements belched forth so abundantly that the temperature of the colder regions was rendered tropical. These and similar theories endeavouring to account for the vestiges of an extinct tropical Europe are at variance with the order of nature on our planet as exemplified by the facts of geology and the principles deduced therefrom. While avoiding both extremes, the theory herein propounded goes in for a greater extension of the obliquity of the ecliptic than astronomers are prepared to admit; while it advocates an amount of volcanic force in the earlier epochs of the earth's formation which no geologist has hitherto advanced. Nevertheless we think, after a calm inquiry into the proposition, there is nothing in it contrary to the universal law of gravitation, or those volcanic forces of which evidence still exists in almost every quarter of the globe. It is a logical solution of an important scientific question, and entitled to further investigation and fair argument.

80. *Computation of Geological Time by Stratified Rocks.*—Without determining the maximum of tropical latitudes at that epoch, there are sufficient data to open up a new mode of computation for the ages of sedimentary rocks. Hitherto geologists, in calculating the lapse of time during the successive epochs of extinct animal and vegetable life, have based their estimates upon observations of recent deposits, considered to be analogous to the matter of certain stratified rocks, con-

taining fossil remains, at the period of their formation. Upon this basis the length of time given to these epochs extends to millions of years. Without disputing the premises on which these estimates are founded, and the undoubted evidence that geological time is inconceivably great, it will be admitted that the basis of calculation is rude and uncertain. A portion of ground is examined where a sedimentary deposit has been made by a river so many inches thick within a known space of time, and the time occupied by the laying down of such deposits is multiplied to ascertain that which would be required for others thousands of feet in thickness. This method of calculation supposes that deposits have been uniform throughout all time, against which there are abundance of geological facts showing that sedimentary deposits have not been thus uniform. For instance, the fact that fossil stems of trees many feet in length are found upright in horizontal strata show that the deposits around them must have been rapid, otherwise the lapse of time would have destroyed that part of the tree exposed to the decomposing action of air or water. Hence, in calculating geological time, enthusiasts are apt to fall into error where they conclude that the process of depositing sedimentary rocks has been uniform from the beginning.

81. *Computation by Extinction of Species.*—Besides that system of computation which is applied to the most recently formed stratified rocks, geologists estimate the antiquity of the more ancient formations by the fossil remains of plants and animals whose species or genera no longer exist. They say that if so many years have elapsed during the most recent era, when some three or four species of shells only have become extinguished, how enormous must have been the lapse of time required to extinguish the hundreds and thousands of species and genera which lie embedded in fossiliferous rocks! But the difficulty again arises as to data of time for the recent era. Here some geologists have called in the aid of astronomy, and, calculating through the precession of the equinoxes, have endeavoured to fix upon a

period when the eccentricity of the earth's orbit was so great that the heat received by the earth from the sun would be one-fifth more in summer than at present, and one-fifth less in winter. Calculating on this basis, which is of a thoroughly scientific and legitimate character, Mr James Croll, a thoughtful Scottish geologist, has endeavoured to show that 800,000 years have elapsed since the time when he considered the glacial period existed—arguing as follows:—

82. *Croll's Estimate of Glacial Period by Precession of the Equinoxes.*—"If, now, by the precession of the equinoxes, winter in our northern hemisphere should happen when the earth is in the aphelion of its orbit at the time of its greatest eccentricity, there would result, according to Mr Croll, such a severity of climate as to bring our mean annual winter temperature below freezing-point. In that case, all the moisture that would fall here would fall in the form of snow; and though when summer came it would be one-fifth warmer than at present, the first effect of that would be to generate fogs and mists, and to intercept the sun's rays, and prevent the heat exercising its due influence—so that Mr Croll conjectures that the ice and snow would never be melted, and in that way he accounts for the world in its glacial period. . . . If we in this way get a beginning, it may be possible in the end to find some approximate value in years for the length of some of our geological periods. We are just groping our way at present, and whatever is stated must be stated with extreme caution, and must be stated rather with the desire of eliciting truth than of pretending to state dogmas."*

83. *Rate of Diminution of Obliquity a Basis for Geological Time.*—Acting in the cautious manner indicated by Mr Geikie, we venture to propose our views on the primeval extension of the obliquity of the ecliptic, and its subsequent diminution, as a basis for computing geological time. It appears to us that once the wings of imagination are let loose by enthusiastic geologists there is no limit to their flight, and

* Lecture on Geological Time, by Archibald Geikie, F.R.S.

they conclude by rushing into boundless time bordering on eternity. In their estimates of epochs they scatter hundreds of thousands, nay millions, of years broadcast over the extinction of species, as if they were the days and months of the geological year in which they existed. As if in a spirit of antagonism to the Mosaic history of the creation, which limits the world's existence to some six thousand years, the advocates for these inconceivable spaces of time seem to glory in showing its infinitesimal degree by the countless ages they have unrolled on the book of the earth's stratified records illustrated in its fossil pages. Steering a middle course between these extremes, we find that, in applying the ascertained diminution of the displacement of the ecliptic during one century, we arrive at an approximate calculation of the time which elapsed since the earth began to recede from its maximum extension of obliquity at the close, or rather the turn, of the tropical epoch in Europe. For example, if the diminution of the ecliptic be 45″ in a century, this would give in 8000 years a decrease of 1°; and taking the maximum of the torrid zone at 45° extension, or 21° 30′ greater than it is at present, the result would be a lapse of 172,000 years since the epoch referred to, when the flora and fauna of Europe were of a similar nature to what now exists within and on the borders of the present tropical limits. According to this theory of constant diminution, a greater lapse of time must take place before the planes of the equator and the earth's orbit are parallel, when the seasons will no longer exist.

84. *Not to be considered arbitrary but suggestive in the Formula of Computation.*—In venturing upon naming a given space of time, numbered by years, to specify the duration of any epoch in the physical history of the world, it by no means follows that it should be taken as an arbitrary system of computing geological time. It shows, however, that geology must go hand in hand with astronomy in determining the age of the earth since it became the abode of organised creatures and plants. If, on the one hand, astronomers were

to descend from abstruse celestial computations, and endeavour to assimilate their investigations with geognostic phenomena, they would materially aid the solution of such problems. On the other hand, geologists would advance the doctrines of their science more logically and acceptably if they avoided arbitrary conclusions from imperfect data, leaving a wide margin for calculating periods in the early epochs of the earth.

CHAPTER V.

EXTINCT TROPICAL EPOCH IN EUROPE.—*Continued.*

Duration and aspect of the tropical epoch in Europe, § 85.—Hugh Miller's sketch of Scotland during this epoch, 86.—Comparison between the aspect of that epoch and the present, 87.—Probable cause of diminution in the inclination of the earth's axis, 88.—Disparity between the land of the two hemispheres greater then than now, 89.—Australian and South African geography present low elevations, 90.—Reactionary volcanic forces in the upheaval of South America, 91.—Physical differences between North and South America, 92.—Remarkable geological analogy between North America and Europe, 93.—Immense extent of active volcanic regions in South America, 94.—Activity of volcanic forces in modern times up to 1868, 95.—Humboldt's first impressions on feeling the shock of an earthquake, 96.—Dread of earthquakes felt by the inhabitants of South America, 97.—Humboldt's account of phenomena attending volcanic eruptions, 98.—Volcanic forces in South America sufficient to cause a reactionary movement in the earth's axis, 99.—Volcanic regions of Central America and Southern Mexico included in this reaction, 100.—Humboldt's account of the extraordinary volcano of Jorullo, 101.—Example of volcanic action typical of that of South America, 103.—Modern volcanic activity chiefly confined to equatorial latitudes, 104.—Volcanic region of Java, 105.—Concluding remarks, 106.

85. *Duration and Aspect of the Tropical Epoch in Europe.*—Assuming that the tropical epoch in Europe was the result of the torrid zone being expanded to forty-five degrees of latitude on each side of the equator, it would have taken 350,000 years to reach its maximum, from the first point of departure, when there was no obliquity of the ecliptic. The next question for inquiry is, Whether the earth remained in that position for any great period, or was by some imme-

diate counteracting volcanic force in an opposite direction arrested in its progress, and the diminution begun? On this head geological data are not so precise as on others; yet the evidence goes to show that the tropical period must have existed for an immeasurable space of time, when not only the fauna and flora of that epoch were brought into existence, but, as far as Europe is concerned, the entire vegetable and animal nature which then flourished, became extinguished. Of the marvels of that period, the following inferential sketch by Hugh Miller, from geological data, forms a graphic picture:—

86. *Hugh Miller's Sketch of Scotland during this Epoch.*—"Could we but see the productions of our country as they once really existed—could we travel backwards into the vanished past, as we can descend into the strata that contain their remains, and walk out into the woods or along the shores of oolitic Scotland—we should be greeted by a succession of marvels, strange beyond even the conceptions of the poet, or at least only equalled by the creations of him who, in his adventurous song, sent forth the lady Una to wander over a fairy-land of dreary wolds and trackless forests, whose caverns were the haunts of dragons and satyrs, and its hills the abodes

> "'Of dreadful beasts, that when they drew to hande,
> Half-flying and half-floating, in their haste,
> Did with their largeness measure o'er much lande,
> And made wide shadow under bulksome waist,
> As mountain doth the valley overcaste;
> And trailing scaly tails did rear afore
> Bodies so monstrous, horribill, and vaste.'

"Let us, however, ere we part for the evening, adventure a short walk into the wilds of Oolite, in that portion of space now occupied on the surface of the globe by the north-eastern hills of Sutherland, where they abut on the precipitous Ord. We stand on an elevated wood-covered ridge, that on the one hand overlooks the blue sea, and descends on the other towards a broad river, beyond which there spreads a

wide expanse of a mountainous country. The higher and more distant hills are dark with pines; and save that the sun, already low in the sky, is flinging athwart them his yellow light and gilding, high over shaded dells and the deeper valleys, cliff, and copse, and bare mossy summit, the general colouring of the background would be blue and cold. But the ray falls warm on the rich vegetation around us, —tree-ferns, and tall club-mosses, and graceful palms, and the strangely-proportioned cycadaceæ, whose leaves seem fronds of the bracken fixed upon decapitated stumps; and along the banks of the river we see tall intensely-green hedges of the feathered equisetaceæ. Brown cones and withered spiky leaves strew the ground, and scarcely a hundred yards away there is a noble araucaria, that raises, sphere-like, its proud head more than a hundred feet over its fellows, and whose trunk, bedewed with odoriferous balsam, glistens to the sun. The calm stillness of the air makes itself faintly audible in the drowsy hum of insects. There is a gorgeous light-poised dragon-fly darting hither and thither through the minuter gnat-like groups; it settles for a moment on one of the lesser ferns, and a small insectiverous creature, scarcely larger than a rat, issues noiselessly from its hole, and creeps stealthily towards it. But there is a whirr of wings overhead, and lo! a monster descends, and the little mammal starts back into its hole. 'Tis a winged dragon of the Oolite, a carnivorous reptile, keen of eye and sharp of tooth, and that to the head and jaws of the crocodile adds the neck of a bird, the tail of an ordinary mammal, and that floats through the air on leathern wings resembling those of the vampire-bat. We have seen, in the minute rat-like creature, one of the two known mammals of this vast land of Oolite—the insect-eating *amphitherium;* and in the flying reptile, one of its strangely-organised *pterodactyles.*

"But hark! what sounds are those? Tramp, tramp, tramp—crash, crash. Tree-ferns and club-mosses, cycas and zamia, yield to the force and momentum of some immense reptile, and the colossal *iguanodon* breaks through. He is

tall as the tallest elephant, but from tail to snout greatly more than twice as long—bears, like the rhinoceros, a short horn on his snout, and has his jaws thickly implanted with saw-like teeth. But, though formidable from his weight and strength, he possesses the comparative inoffensiveness of the herbivorous animals; and with no desire to attack, and no necessity to defend, he moves slowly onward, deliberately munching, as he passes, the succulent stems of the cycadaceæ.

"The sun is fast sinking, and, as night thickens, the reaches of the neighbouring rivers display their frequent dimples, and ever and anon scaly backs are raised over its surface. Its numerous crocodilians are astir, and now they quit the stream, and we see its thick hedge-like lines of equisetaceæ open again and close, as they rustle through, to scour, in quest of prey, the dank meadows that line the banks. There are tortoises that will this evening find their protecting armour of carapace and plastron all too weak, and close their lives of centuries. And now we saunter downwards towards the shore, and see the ground-swell breaking white in the calm against ridges of coral scarce less white. The shores are strewed with shells of pearl, the whorled *ammonite*, and the *nautilus;* and amid the gleam of ganoidal scales, reflected from the green depths beyond, we may see the phosphoric trail of the *belemnite*, and its path is over shells of strange form and name—the sedentary *gryphæa*, the *pama*, and the *plagiostoma*.

"But lo! yet another monster. A snake-like form, surmounted by a crocodilean head, rises high out of the water within yonder coral ledge, and the fiery sinister eyes peer inquiringly round, as if in quest of prey. The body is but dimly seen; but it is short and bulky compared with the swan-like neck, and mounted on paddles instead of limbs; so that the entire creature, wholly unlike anything which now exists, has been likened to a boa-constrictor threaded through the body of a turtle. We have looked upon the *plesiosaurus*. And now outside the ledge there is a huge

crocodilean head raised; and a monstrous eye, huger than that of any other living creature—for it measures a full foot across—glares upon the slimmer and less powerful reptile, and in an instant the long neck and small head disappear. The monster of the immense eye—an eye so constructed that its focus can be altered at will, and made to comprise either near or distant objects, and the organ itself adapted either to examine microscopically or to explore as a telescope — is another be-paddled reptile of the sea, the *ichthyosaurus*, or fish-lizard.

"But the night comes on, and the shadows of the woods and rocks deepen; there are uncouth sounds along the beach and in the forest; and new monsters of yet stranger shape are dimly discovered moving amid the uncertain gloom. Reptiles, reptiles,—flying, swimming, waddling, walking,—the age is that of the cold-blooded, ungenial reptile; and, save in the dwarf and inferior forms of the marsupials and insectivora, not one of the lowest mammals has yet appeared. And now the moon rises in clouded majesty; and now her red wake brightens in one long strip the dark sea; and we may mark where the *cetiosaurus*, a sort of reptilian whale, comes into view as it crosses the lighted track, and is straightway lost in the gloom. But the night grows dangerous, and these monster-haunted woods were not planted for men. Let us return, then, to the safer and better furnished world of the present time, and to our secure and quiet homes." *

87. *Comparison between the Aspect of that Epoch and the Present.*—As far as his native country is concerned, the weird-thinking Scottish geologist is right, but not as regards the inhabitants of tropical regions in Asia, Africa, and America, where man is still surrounded by dangerous reptiles and quadrupeds, of different forms, no doubt, but equally voracious. There is no evidence that man did exist at that period; at the same time there is nothing to assure us that he could not have existed. Let us imagine under what different circum-

* Hugh Miller—'Sketch-Book of Popular Geology.'

stances the inhabitants of the British Isles would have toiled for their subsistence then to what obtains now, or if the climate had never changed from its tropical character to the present temperate one, with the vicissitudes of the seasons. Instead of the hardy independent race that now tills the ground, sowing and reaping the golden grain, rejoicing in the spring-time and harvest, or spreading their flocks and herds over the pasture-lands, there would have been in all probability some black race as in Africa, of degraded intellect, or a red race as in India, effeminate and servile, living on the fruits of the forest, and exposed to the ferocious attacks of animals. Instead of the open forest-land and greensward, with the hardy oak and elm, there would be a dense jungle of succulent shrubs, trees, and arborescent ferns; and instead of the balmy breezes of summer and autumn, we should be breathing a damp, hot, suffocating atmosphere, charged with deadly malaria, like what may be found in African forests.

88. *Probable Cause of Diminution of Inclination in the Earth's Axis.*—Having traced the displacement of the equatorial plane from the earth's orbit to its maximum extent, we now proceed to investigate the cause of its diminution. We have seen how the plutonic forces in the interior were most intensely manifested by the upheaval of continental masses in the north hemisphere. We can also understand how the masses of igneous rock, after rending the earth's crust, became solidified until the rents were closed. Then the confined volcanic forces were directed towards the south hemisphere, piercing through the stratified rocks at the weak points and fissures along the chain of the Andes with such tremendous force, that it not only arrested the further extension of the tropical zones, but had the effect of counteracting the forces in the north hemisphere; and then commenced the diminution of this phenomenon, which has continued to the present era. On this point geology informs us that the bulk of the mountain-chains and elevated table-lands, especially in the more northern parts of the continents of Europe, Asia, and North America, is composed of the crystalline schistous formation,

comprehending all the granitoid rocks, and the primary stratifications, or the transition series, including the carboniferous formation; while South America is chiefly of secondary and tertiary strata, with igneous rocks of recent formation; and as far as we know of Australia, New Zealand, and the islands in the South Pacific, they partake chiefly of similar geological features. At all events, there are enough data for concluding that the continental masses of the south hemisphere (excepting, perhaps, South Africa) were upheaved, for the most part, subsequent to the upheaval of the northern continents—especially the preponderating masses of the Himalayas, and other mountain-chains of the primary series in Asia and in North America.

89. *Disparity between the Land of the two Hemispheres greater then than now.*—On referring to our map of the world on the polar projection, where the globe is bisected at the equator, we may see, at a glance, the immense superficies of land above the level of the sea at the present period in the north hemisphere as compared with the south. Great as the disproportion is now, it was probably more so at the epoch when the earth received the vertical rays of a tropical sun in Europe. As far as geological researches have revealed the extent of land and sea at that era, it would appear that while the area of the primary and secondary formations equalled that of the ocean in the north hemisphere, in the south the few islands that comprised that series of rocks, rising above the then level of the sea, scarcely covered a hundredth part of its boundless domain. At that period the island-continent of Australia comprised two narrow chains of isles, one in its present eastern longitudes, the other in the west, and both trending north and south, with a shallow sea between, which has been slowly upheaved until its bed formed the level, marshy, saline districts characterising the interior geography of that extensive territory, which nearly equals the area of Europe. On the other hand, these groups of isles must have been of comparatively low elevation, as we find, notwithstanding the extent of this region, that the crest of

its great eastern mountain-chain of 1700 miles is not more than 2000 feet above the sea-level, and Mount Kosciusko, in the Australian Alps, its highest ascertained peak, only 6500 feet. "From the absence of any great mountains commensurate with the enormous extent of country, and from the general horizontal formation of its rocks, it has been inferred that the convulsions of the globe have been less active in this region than on the other continents. No active volcanoes are seen among its mountains, nor do recent strata indicate their existence. Its surface geology, therefore, presents a region undisturbed since the tertiary epoch; at the same time it is evident that the upheaval of the country has been regular though slow, and some geologists have observed that it is still going on in certain localities. Be that as it may, Australia may be regarded as representing an extinct archipelago, with its sea-bed upheaved beneath the rays of a burning sun, which through ages has dried up its superincumbent waters. The sea became shallower from evaporation and continued upheaval, until it has disappeared, except in the chasms and depressions of the old ocean-bed, where it still remains, forming the salt lakes of the west and central parts —the former above the level of the present sea, and some of the latter with the adjacent land below it. During that epoch, those streams which now flow through the marshy interior from the mountain-chains once mingled their floods with the tide that rippled upon their shores, when they were islands studding the extinct Australian sea." *

90. *Australian and South African Geography present low Elevations.*—This basin-like form, with elevated lands fringing the coast around a depressed interior, characterises the geography of South Africa also, bearing out the theory of slow elevation of the continental mass, without any evidence of recent eruptive rocks or active volcanoes. From the researches of Dr Livingstone, who crossed the interior from west to east, and nearly from north to south, we learn that there are no mountain-chains of elevation proportioned to the

* 'Our Australian Colonies.' By Samuel Mossman.

extent of the continent in that hemisphere. In crossing the widest part, from the Atlantic to the Indian Ocean, he found elevated ridges from 300 to 350 geographical miles from the coast, and trending in a general north and south direction. From crest to crest of these ranges he estimated the distance at 400 geographical miles, and the highest culminating point at 5000 feet above the sea-level; consequently he came to the conclusion that the greater portion of South Africa is a vast interior basin, enclosed by extensive rocky ridges, except where they are broken to admit the outlet of the waters collected therein. In one respect the geography here differs from Australia, as the interior basin is at a greater elevation, and the fringe of mountains on either side is further from the coast. Nevertheless there is a striking similarity in the general configuration, and sufficient data to conclude that at a contemporary epoch South Africa presented only chains of islands scattered over an African archipelago, with a shallow sea between, which plutonic forces have gradually upheaved, until the ocean-waters have departed, and their place is supplied by numerous fresh-water lakes and streams. At this period the mighty Himalayas, the gigantic table-land of Tibet, with its mountain-chains, the Celestial Mountains, and the steppes of Tartary, in Asia—the Alps and the Pyrenees in Europe—the Rocky Mountains and the table-lands of Mexico in North America—and all the circle of rugged eminences within the circumpolar regions,—then weighed down the comparative "world of waters" which encircled their antipodes in the south hemisphere, and thus disturbed the equilibrium of the globe so as to displace the planes of its diurnal and annual rotation. So that we may conclude, as far as the continental masses of South Africa and Australia influenced the reaction of internal forces, or counterbalanced the land in the north hemisphere, they exercised comparatively an inferior power; and if our theory of terrestrial action in the south hemisphere producing diminution of the tropics was based upon their geological data, it would be inadmissible and unscientific.

91. *Reactionary Forces in the Upheaval of South America.*

—But we have yet to consider the vast continent of South America, with its stupendous mountain-system—the backbone of the world—the mighty Andes. If the human mind could only conceive the tremendous volcanic forces brought to bear on that latitudinal line of five thousand miles, rending the south hemisphere, as it were, in twain, there would be no difficulty in imagining the shock that arrested the deflection of the earth's axis in its equatorial career. If man could have witnessed the depth and length of the awful fissure which yawned on the earth's crust at the epoch of their creation—when the incandescent rock was erupted from its subterranean source, in masses so overwhelming that not only were the deepest parts of the ocean filled up, but the highest elevations above the sea-level attained—then might we conceive the awful convulsion that made the terraqueous globe quake from the equator to the poles, causing a reaction towards the restoration of its equilibrium which has ever since progressed by the diminution of the torrid zone, until that zone has entirely left the continent of Europe. Notwithstanding the difficulty, almost amounting to a mental impossibility, of forming a vivid conception of this stupendous event in the world's geological history, we can form some approximate idea of the volcanic forces engaged in the upheaval of the Andes or Cordilleras from the graphic descriptions of scientific travellers—especially those of Humboldt—who have witnessed the vestiges of this creation in the volcanic eruptions and earthquakes which still agitate the South American continent. Before doing so, however, it will be necessary to refer briefly to the North American continent in its geological relations with Europe and Asia as contrasted with its southern sister.

92. *Physical Differences between South and North America.* —Although the two great divisions of the American continent are united together by the volcanic band of Central America, thereby tending to convey the impression that they are homogeneous in their physical relations, yet no two regions on the earth are so dissimilar in their geognostic phenomena, fauna, and flora. After the discovery of their

entire extent by Columbus, Americus, and their fellow-navigators of the fifteenth century, the astounding length of the coast-line from north to south, and, as far as was then known, their width from the shores of the Atlantic to the Pacific, appeared so immense, together with all the strange inhabitants, animals, and plants, hitherto unknown to Europeans, that, with one accord, this land was designated the "New World" in contradistinction to the appellation of the "Old World" bestowed on Europe, Asia, and Africa. In its general meaning the term was appropriate at the time, as briefly including all the vast territories in the western hemisphere. It is time, however, that these names should become obsolete, especially in works of a scientific nature, as they are apt to mislead the general reader in his impressions concerning the continental divisions of the world.

93. *Remarkable Geological Analogy between North America and Europe.*—Not only is North America physically distinct from the southern continent in its main features, but these possess a striking similarity to the physical phenomena of Europe, more especially in geological structure and fossil remains. "A remarkable analogy exists in the structure of the land in North America and Central and North Europe. Gneiss, mica-schist, and granite prevail over wide areas in the Alleghanies; on the Atlantic slope, and the northern latitudes of the American continent, and in the high and middle latitudes, the Silurian strata extend over 2000 miles. Crystalline and Silurian rocks form the substratum of Mexico, for the most part covered with plutonic and volcanic formations and secondary limestone. The Rocky Mountains are mostly Silurian, except the east ridge, which is of stratified crystalline rocks, amygdaloid, and ancient volcanic productions." * It is well known that the Silurian formation is named after a district in England where it abounds, and which was formerly inhabited by an ancient tribe of Britons named Silures. The formation itself is remarkable for exhibiting the fossil remains of the earliest types of animal life,

* 'Imperial Gazetteer,' edited by W. G. Blackie, Ph. D.

as represented by mollusca and zoophytes, the genera and species being analogous in both Europe and America. In like manner the remains of vertebrate animals found in North America, as well as those of its extinct flora, are either identical with, or congeners of, those which existed in Europe during the tropical epoch. Indeed the geological data of the two countries go to prove their contemporary existence during the earliest ages of the world, and at a period, as we have seen, when the continental masses of the south hemisphere were only in their infancy, peeping above the primeval ocean, or small islets before consolidation. Moreover, it may be said that these northern regions had attained their geological maturity, and were progressing towards old age, which ultimately verged into decay, death, and extinction of species, leaving behind them the ruins of what ought to be designated scientifically the "Old World," as distinguished from what now exists on the surface of the earth, which is actually a "New World" of creation. Viewing the physical aspect of the North American continent in this light, it is not a new region, but forms a grand member of the continental masses in the ancient northern world.

94. *Immense Extent of Volcanic Regions in South America.*—On the other hand, the South American Cordilleras, to which we may join the volcanic band of Central America, are comparatively of recent igneous formation; while the boundless plains of the interior are evidently of modern upheaval, with the immense area drained by the river Amazon presenting alluvial deposits formed by that queen of rivers, and the Pampas of Buenos Ayres entirely alluvium, deposited by the Plata-Parana. But it is in the Andes that we find those examples of the subterranean forces of the earth which are truly the grandest volcanic wonders of the world. "In considering the geology of the Andes, the first fact that strikes the observer is the vast development of volcanic force along the whole length of the chain, and even continued north through Guatemala and Mexico. These volcanic vents seem to occur in linear groups, the southmost of which is Chile,

extending from the 42d to the 33d parallel, and comprising, besides more than a dozen extinct volcanoes, twenty-one still in a state of ignition, the more remarkable of which are Tupungato (15,100 ft.), Antuco (13,000 ft.), and Minchinmaddom (8000 ft.) From the 30th to the 27th parallels no volcanic action is to be found; but in the Bolivian Andes, and principally west of Lake Titicaca, are eight active craters, among which may be mentioned Gualatieri (22,000 ft.), Atacama (18,000 ft.), Chipicani (19,740 ft.), and Arequipa (18,400 ft.) Further north, as far as the 2d parallel south, there are no active volcanoes; but here we arrive at a district of highly volcanic character, comprising other eight lofty summits now in an igneous state—Sangay, Tunguragua, Cotopaxi, Antisana, Imbabura, Cumbal, Pasto, and Purace. As respects the geological formations of this gigantic range, granite, which is abundant in Tierra del Fuego and Patagonia, seems to be the base of the whole, but it comes so rarely to the surface in the north parts of the chain, that, according to Humboldt, a person might travel years in the Andes of Peru without meeting this species of rock; and he never saw any at a greater absolute elevation than 11,500 ft. Gneiss is sometimes found in connection with the granite, but mica-schist is by far the commonest of all the crystalline rocks. . . . As respects volcanic products, the west face of the Andes presents immense quantities of lava, tufa, and obsidian, none of which are found on the east side; this remark applies especially to that part of the chain lying between Chile and the equator. Fossil remains are by no means common; but in the limestone strata of the coast, towards the north extremity of the range, Humboldt found many marine shells." * Without entering minutely into the geology of this region, it is abundantly evident that the great bulk of the continental mass was upheaved to its present heights above the waters of the Atlantic and Pacific subsequent to the elevation of the northern continent.

95. *Activity of Volcanic Forces in Modern Times up to*

* 'Imperial Gazetteer.'

1868.—"Many of the volcanoes, as before observed, are in a state of either constant or occasional action; it cannot, therefore, be matter of surprise that there should be frequent and violent earthquakes. All the districts of the Andes system, but Chile especially, have suffered more severely from these oscillations than any other part of the world; and among the towns either destroyed or greatly injured by these visitations may be mentioned Bogota, Quito, Riobamba, Lima, Callao, Valparaiso, and Concepcion."* In 1797, Riobamba, Tacunga, and Hambato were levelled to the ground. The earth opened under the feet of the inhabitants, and whole caravans were swallowed up, besides habitations; while avenues of trees were shifted from one spot to another without the trees being in the least damaged. In 1822 Chile was severely visited, and an upheaval of 100,000 square miles of ground to a height of seven feet was the result of the volcanic force. But by far the most extensive and calamitous earthquakes of modern times are those of which Ecuador, Peru, and Bolivia were the centres of oscillation in August 1868, which are still fresh in our recollection. On the evening of the 13th of that month, about 4 P.M., the first shocks were felt, and continued at intervals during the night with unprecedented violence, even in that region of earthquakes. In the course of a few hours the oscillations of the unstable ground completely destroyed the towns of Arequipa, Moquegua, Arica, Pisagua, Iquique—doing, besides, immense damage to a number of other places all along the coast from Iquique to Callao. At Arequipa the shocks commenced at 5.22 P.M., more or less, and lasted six to seven minutes, followed during the night by eighteen others at intervals, but not so violent. Not a church was left standing, not a house habitable; and had they commenced about midnight few would have survived to tell the tale. At Tacna the shock was almost as destructive; and at Arica the buildings which withstood the earthquake were washed down by the sea, which broke over the town shortly after the first shock. An eyewitness and sufferer at

* 'Imperial Gazetteer.'

Iquique describes the rising of the sea as follows:—"I saw the whole surface of the sea rise as if a mountain-side was actually standing up. Another shock, accompanied with a fearful roar, now took place. I called to my companions to run for their lives on to the Pampa. Too late! With a horrid crash the sea was upon us, and at one swoop—one terrible swoop—dashed what was Iquique on to the Pampa. I lost my companions, and in an instant was fighting with the dark waters. The mighty wave surged and roared and leaped. The cries of human beings and animals were dreadful. A mass of wreck covered me and kept me down; and I was fast drowning when the sea threw me on to a beam, but a nail piercing my coat, the timber rolled me again under, and I lost all sense. I suppose, as in such cases, I must have struggled after sensation had left me, for when returning consciousness came I was grasping under one arm a large plank, the broken end of which afterwards pierced my thigh. I knew no more until I found myself on the Pampa and all dark around me. In the morning I looked about me and found Iquique gone, all but a few houses round the church." While the proximity of the sea added to the devastations of the towns on the coast, those in the interior suffered an equal destruction of property from the greater violence of the shocks, and as they occurred later in the night, when the inhabitants had retired to rest, the number of people killed by the falling houses was tenfold greater in proportion to the population. At Otavalo, Ibarra, and Catacachi almost every building was overthrown, and the number who perished in the ruins was overwhelming, as the terror of the calamity was increased by its occurrence at midnight. Ibarra is about twenty leagues from Quito, situated on a plain 7000 feet above the level of the sea. Its population was estimated at 29,000, of whom fully 13,000 perished in the ruins. Otavalo is to the east of Ibarra, about 9000 feet above the sea-level, having a population of 10,000, of whom about 7000 perished. These towns and Catacachi are in the province of Imbabura, containing a population altogether of

about 65,000; and it was estimated that upwards of 40,000 perished on that fearful night. Nearly every village in the province had become a mass of ruins by the time daylight unfolded the true extent of the devastation, and the losses of relatives and friends sustained by the inhabitants. Many of the victims buried under the ruins suffered a lingering death from the inability of the few survivors to extricate them. And as decomposition sets in rapidly in these latitudes, it was impossible afterwards to go into the vicinity of the awful scenes of dissolution, owing to the decomposition of so many human bodies. As far as could be ascertained, the number who perished in these earthquakes was not less than 60,000, while the value of the property destroyed was incalculable.

96. *Humboldt's First Impressions on the Hearing of an Earthquake.*—It would be an easy task to multiply examples of the terrible effects in that region from the pent-up subterranean forces which make the old crust of the earth yield like a piece of cardboard to their pressure, and cause the land to undulate like the waves of the sea. "We thus recognise in earthquakes the existence of a volcanic force which, although everywhere manifested and as generally diffused as the internal heat of our planet, attains but rarely, and then only at separate points, sufficient intensity to exhibit the phenomena of eruptions." Thus writes Humboldt in 'Cosmos,' and afterwards describes his experiences of earthquakes as follows:—"Before we leave these important phenomena, which we have considered not so much in their individual characteristics as in their general physical and geognostic relations, I would advert to the deep and peculiar impression left on my mind by the first earthquake which we experience, even where it is not accompanied by any subterranean noise. This impression is not, in my opinion, the result of a recollection of those fearful pictures of devastation presented to our imagination by the historical narratives of the past, but it is rather due to the sudden revelation of the delusive nature of the inherent faith by which we had clung to a belief in the immobility of

the earth. We are accustomed from early childhood to draw a contrast between the mobility of water and the immobility of the soil on which we tread; and this feeling is confirmed by the evidence of our senses. When, therefore, we suddenly feel the ground move beneath us, a mysterious and natural force with which we were previously unacquainted is revealed to us as an active disturbance of stability. A moment destroys the illusion of a whole life—our deceptive faith in the repose of nature vanishes, and we feel transported, as it were, into a realm of unknown destructive forces. Every sound—the faintest motion in the air—arrests our attention, and we no longer trust the ground on which we stand. . . .' To man the earthquake conveys an idea of some universal and unlimited danger. We flee from the crater of a volcano in active eruption, or from the dwelling whose destruction is threatened by the approach of the lava-stream; but in an earthquake, direct our flight whithersoever we will, we still feel as if we trod upon the very focus of destruction." *

97. *Dread of Earthquakes felt by the Inhabitants of South America.*—"Dr Tschudi, in his interesting work, 'Travels in Peru,' describes strikingly the effect of an earthquake upon the native and upon the stranger. 'No familiarity with the phenomenon can blunt this feeling. The inhabitant of Lima, who from childhood has frequently witnessed these convulsions of nature, is roused from his sleep by the shock, and rushes from his apartment with the cry of *Misericordia!* The foreigner from the north of Europe, who knows nothing of earthquakes but by description, waits with impatience to feel the movement of the earth, and longs to hear with his own ear the subterranean sounds which he has hitherto considered fabulous. With levity he treats the apprehension of a coming convulsion, and laughs at the fears of the natives; but as soon as his wish is gratified he is terror-stricken, and is involuntarily prompted to seek safety in flight.'" †

98. *Humboldt's Account of Phenomena attending Volcanic Eruptions.*—"Volcanoes which, like the chain of the Andes,

* Humboldt's 'Cosmos.' † Ibid., translator's note.

lift their summits high above the boundaries of the region of perpetual snow, present peculiar phenomena. The masses of snow, by their sudden fusion during eruptions, occasion not only the most fearful inundations and torrents of water, in which smoking scoriæ are borne along on thick masses of ice, but they likewise exercise a constant action whilst the volcano is in a perfect state of repose, by infiltration into the fissures of the trachytic rock. Cavities, which are either on the declivity or at the foot of the mountain, are gradually converted into subterranean reservoirs of water, which communicate by numerous narrow openings with mountain streams, as we see exemplified in the highlands of Quito. The fishes of these rivulets multiply, especially in the obscurity of the hollows, and when the shocks of earthquakes, which precede all eruptions in the Andes, have violently shaken the whole mass of the volcano, these subterranean caverns are suddenly opened, and water, fishes, and tufaceous mud are all ejected together. . . . Amongst all the volcanoes I have seen in the two hemispheres," Humboldt remarks, "the conical form of Cotopaxi is the most beautifully regular. A sudden fusion of the snow at its cone of cinders announces the proximity of the eruption. Before the smoke is visible in the rarified strata of air surrounding the summit and the opening of the crater, the walls of the cone of cinders are sometimes in a state of glowing heat, when the whole mountain presents an appearance of the most fearful and portentous blackness. The crater which, with very few exceptions, occupies the summit of the volcano, forms a deep caldron-like valley, which is often inaccessible, and whose bottom is subject to constant alterations. . . . Long narrow fissures, from which vapours issue forth, or small roundish hollows filled with molten masses, alternately open and close in the caldron-like valley; the bottom rises and sinks, eminences of scoriæ and cones of eruption are formed, rising sometimes far over the walls of the crater, and continuing for years together to impart to the volcano a peculiar character, and then suddenly fall together and disappear during a new erup-

tion. The openings of these cones of eruption, which rise from the bottom of the crater, must not, as is too often done, be confounded with the crater which encloses them. If this be inaccessible from extreme depth, and from the perpendicular descent, as in the case of the volcano of Rucu-Pichincha, which is 15,920 feet in height, the traveller may look from the edge on the summits of the mountains which rise in the sulphureous valleys at his feet; and I have never beheld a grander or more remarkable picture than that presented by this volcano."*

99. *Volcanic Forces in South America sufficient to cause a Reactionary Movement of the Earth's Axis.*—If this volcanic region of South America presents such terribly grand features of the subterranean forces at work in the continued upheaval of the continent when they may be said to be in a comparatively quiescent state, what must have been the effects of the tremendous convulsions that first raised a few groups of isles into a vast continental mass, consolidating its western boundary on the Pacific by a wall of igneous rocks five thousand miles in length, from two hundred to three hundred miles wide at its crest, and rising from the bed of the ocean to a perpendicular height of eight miles, or about fifty thousand feet! Let us conjure up in imagination the awfully sublime aspect of nature in these regions during that period; when the laws that had governed the declination of the sun on this planet were in a measure suspended, and a reaction commenced in the contraction of its torrid zone, tending to restore again its primary equilibrium. Not all the poetic descriptions of Dante in the 'Inferno,' or the chaotic pictures of Martin in his Biblical illustrations, could represent the labours of the earth in giving birth to these the latest, but not least, offspring of her incandescent womb of molten rocks. Let us imagine the sea boiling, bubbling, and steaming above the domes of red-hot trachyte, swelling and bursting as they rose towards its surface, and then ejecting through volcanic cones and yawning fissures such masses

* Humboldt's 'Cosmos.'

of lava as to form so many thousand miles of mountains; let us conceive the shocks and quakes of the earth in this era of her travail, when the pent-up volcanic forces caused her to rend the solid framework of her sphere, a perturbed daughter of the sun, the most convulsive child of the solar system;—and then we may conclude that the counteraction of these plutonic forces, together with the counterpoise of this protuberance of the globe in the south hemisphere, had the effect of giving it an impetus of reaction towards the adjustment of its equilibrium, lessening the angle of its axis, and reducing the displacement of the equatorial plane from that of its orbit—a conclusion that is inconsistent with the laws neither of astronomy nor geology.

100. *Volcanic Region of Central America included in this Reaction.*—In attributing to the sudden upheaval of the igneous mountain-chains of South America the diminution of the displacement of the ecliptic by reason of the counteraction of force and counterpoise of weight against North America, Europe, and Asia, we include the region of Central America and part of Mexico. Although these are situated in the north hemisphere, yet we contend that they added their quota to the general result; inasmuch as the volcanic formations there are contemporary with those in the south hemisphere, and subsequent in their action to the igneous rocks and mountain-chains of the North American continent. Moreover, having assumed that the obliquity of the ecliptic extended at that epoch to forty-five degrees, these equatorial centres of volcanic force would act with the southern forces already established, and against the general preponderance of land in the northern regions. As an example of the recent upheaval and volcanic activity of Southern Mexico, we shall instance the volcano of Jorullo, described in Johnston's 'Physical Atlas,' accompanied by a plan from Humboldt's account of New Spain, as follows:—

101. *Southern Mexico also comprised in the great Volcanic Band.*—"The great catastrophe which caused the upheaval of this mountain from the surface of the earth, and through

which a country of considerable extent totally changed its appearance, is perhaps one of the most extraordinary physical revolutions which the annals of the history of our planet present. Geology describes the shores of the ocean, where, up to recent times, during a course of two thousand years, near the Azores, in the Ægean Sea, and at the south of Iceland, volcanic isles have elevated themselves above the surface of the water; but it presents no other example where, in the interior of a continent, at a distance of thirty-six leagues from the shores of the ocean and more than forty-two leagues from any other active volcano, there was formed suddenly, in the centre of a profusion of burning little cones, a mountain of scoriæ and ashes to a height of nearly 1760 feet above the former level of the neighbouring plains."

102. *Humboldt's Account of the extraordinary Volcano of Jorullo.*—"The plain of Malpays, on which the volcano is situated, forms part of an elevated plateau, from 2000 to 3000 feet above the level of the sea. Until the middle of the eighteenth century, fields, in which the sugar-cane and indigo were cultivated, extended between the two rivulets called Cuitumba and San Pedro. They were bounded by basaltic mountains, the structure of which clearly indicated that at a remote period the whole country had been the theatre of volcanic action. These fields, watered artificially, belonged to the plantation of San Pedro de Jorullo, one of the richest regions of the country. In the month of June 1759 a subterranean noise was heard; frightful bellowings were accompanied by frequent earthquakes, which succeeded each other during fifty or sixty days, and threw the inhabitants of the *hacienda* into the greatest consternation. From the commencement of the month of September perfect tranquillity seemed to be restored, when in the night between the 28th and 29th of the same month, a dreadful subterranean concussion was again observed. The terrified Indians sought for safety on the mountains of Aguasarco. On this occasion the ground which is called the Malpays, to an extent of from three to four square miles, was raised in the form of a blad-

der, to a height of 550 feet above the plain at its highest point."

103. *An Example of Volcanic Action typical of that in South America.*—"The Malpays, towards its sides, has an elevation of only forty feet above the level of the former plain, called the *Playas de Jorullo*; but the convexity of the upheaved soil rises progressively towards the centre to a height of 525 feet. Those who, from the summit of Aguasarco, witnessed this great catastrophe, assert that flames were seen to burst from the ground over an extent of more than half a league square; that fragments of incandescent rocks were thrown to a prodigious height; and that across a thick cloud of ashes, lighted up by the volcanic fire, it appeared as if the softened crust of the earth was swelling. Then the rivers Cuitimba and San Pedro were precipitated into the burning crevices. The decomposition of the water contributed to revive the flames, which were distinguished at the town of Pasewaro, although situated on a broad plateau, and elevated 1500 feet above the plains of *las Playas de Jorullo*. Eruptions of mud, and especially of beds of clay, in which balls of decomposed basalt were enveloped, seemed to indicate that subterranean waters had played a most important part in this extraordinary revolution. Thousands of little cones, from six to ten feet in height, termed by the natives ovens (*hornitos*), arose upon the upraised vault of the Malpays. Each little cone was a fumerole, from which dense smoke ascended to a height of from thirty to fifty feet. In many of these cones a subterranean noise was heard, which appeared to indicate the proximity of a fluid in a state of ebullition. In the middle of these *hornitos* six volcanic cones were formed upon a chasm, in a direction of north-north-east to south-south-west, each elevated from 1300 to 1600 feet above the former level of the plain. The highest of these enormous cones is the great volcano of Jorullo, 1682 feet above the level of the plain, and 4265 feet above the sea. Great eruptions of the central volcano continued until the month of February 1760, but in succeeding years they have become progressively more rare. The Indians, frightened by

the dreadful turmoil caused by the new volcano, at first abandoned the villages situated at a distance of seven or eight leagues from the *Playas de Jorullo;* but in a few months they became accustomed to the frightful spectacle, and returning to their cabins, they descended towards the mountains of Aguasarco and Santa Ines, in order to admire the jets of flame thrown out by an infinity of great and little volcanic mouths. The ashes then covered the roofs of the houses in Queretaro, at a distance of more than forty-eight leagues in a straight line from the place of explosion." At the period of Humboldt's visit there was no apparent volcanic activity, and the ground was being covered with vegetation; yet the heat from the little ovens was so great that it increased the temperature of the air to 109° in the shade.

104. *Modern Volcanic Activity chiefly confined to Equatorial Latitudes.*—In this most remarkable instance of the volcanic elevation of mountains, as witnessed by individuals of the human race capable of handing down a record, we obtain a glimpse into the operations of nature during the past; showing with what suddenness, in point of time, a level plain is transformed into a mountainous district. All that the intelligent mind has to do, in conceiving the elevation of the Andes, or the volcanic mountain-systems of Central America and Southern Mexico, is to magnify, in imagination, the volcano of Jorullo to that of Cotopaxi, and the Malpays country to the height of the table-lands of Quito. Not, be it observed, that these were elevated to their present altitude in an equally short space of time, but that the plutonic forces, and masses of eruptive rocks, were on a scale proportionate to their magnitude. It is only by such degrees of comparison that we can arrive at any conception of the magnitude of igneous operations on the crust of the earth, either recently or in ancient epochs.

We see also, in this example of modern volcanic mountains, the activity of igneous subterranean action that still prevails on the confines of the equator, from which we may conclude that it was not until the great vents in the north hemi-

sphere were closed, and afterwards in the higher latitudes of the south hemisphere, that the internal plutonic forces found a weakness in the shell of the earth, through which they exploded in an equatorial direction. It has been pointed out that the great centres of volcanic action in the north swelled to their maximum extent, if not elevation, in those latitudes midway between the north pole on the one hand and the equator on the other; and that the sequence of action among the primary formations appears to have progressed in an equatorial direction—that as the more northern fissures were closed up by the cooling rocks forming dykes and mineral veins, the waves of ebullition proceeded southwards. In like manner we find in the South American continent the most active volcanic region in tropical latitudes, and an extinct igneous series of mountains in the extreme south, including the groups of rocky islands. Of course the great chain of the Andes is broken in its volcanic series; and we cannot point out the fulfilment of this law so clearly as in the North American mountains, or the mountain-systems of Asia. At all events, there are sufficient data to show that during the latest geological era, and in the present period, the great centres of volcanic action are chiefly directed towards the equatorial zone, as if that were the thinnest part of the earth's crust, or the points through which, as weakest, the pent up volcanic matter can most readily find an outlet.

105. *Volcanic Region of Java.* Not only have we an example of this phenomenon in the western hemisphere, but in the far East there is almost a counterpart in the Indian Archipelago. The island of Java presents a linear series of volcanoes similar to that of Central America, and the adjacent isles bristle with volcanic cones, even to the Philippines. It is a wonderful region altogether of volcanic phenomena, presenting some features not manifested by its western contemporary. In Java "all the mountains may be considered as volcanoes, active or dormant. When in an active state they are remarkable for the quantity of sulphur and sulphureous vapours they discharge. Many of the eruptions have been peculiarly dis

astrous. The crater of Taschem, at the east end of the island, contains a lake, about a quarter of a mile long, strongly impregnated with sulphuric acid, from which there issues a stream of acid water so destructive to life that even fish cannot live in the sea near its mouth An extinct volcano near Batar, called Guevo Upas, or the vale of poison, about half a mile round, is held in horror by the natives Every living creature that enters it drops down dead, and the soil is covered with carcasses of deer, birds, and even the bones of men, killed by the noxious deadly gases that lie at the bottom of the valley." "In another crater in this land of wonders," says Sir Charles Lyell, "the sulphureous exhalations have killed tigers, birds, and innumerable insects; and the soft parts of these animals, such as the fibres, muscles, hair, and skin, are very well preserved, while the bones are corroded and entirely destroyed."

106. *Concluding Remarks.*—Here we conclude our view as to the probable causes that produced the extinct tropical epoch in Europe, and proceed to review the geological evidence of its decline through vast periods of a transitionary character. Casting a retrospective glance at the ancient aspect of our country, it is evident that there was as great a difference—if not a greater—between the physical geography of the British Isles at that period and their present condition, as now exists between them and the isles of Java. In all probability we see there an existing example not only of the intense solar heat which once prevailed here, but, in the gaseous exhalations from volcanoes and their eruptive action, examples of the terrestrial forces of the interior which acted at that period on the exterior of our present quiescent temperate group of islands. Shall it be said, then, that there has been no greater change than might arise from an alteration in the elevation or subsidence of the present lands above the level of the sea? Is it not more probable that Java, "this land of wonders," is typical, not only of the British Isles, but of Europe, Asia, and North America during the extinct tropical eras that formerly existed throughout the temperate regions of the earth?

CHAPTER VI.

TRANSITION PERIODS OF THE TROPICAL EPOCH IN EUROPE.

Humboldt's views on geological exhalations of carbonic acid gas, § 107.—Carboniferous era in Europe ante tropical, 108.—Absorption of carbonic acid gas by the plants forming the coal-deposits, 109.—This period isolated from subsequent transition periods, 110.—Probable extension of the tropics during the carboniferous era, 111.—General view of epochs according to tropic extension, maximum, and diminution, 112.—Extinct organic world compared to rise and fall of the Roman empire, 113.—Migration of animals and extinction of plants during transition periods, 114.—Miocene period, 115.—Pliocene and pleistocene periods, 116.—Advent of the glacial period difficult of explanation, 117.—Forbes's description of glacial phenomena in the Alps, 118.—Application of our theory to account for glacial period, 119.—Its duration computed according to the rate of diminution of the tropical zone, 120.—Glacial period extinguished the fauna and flora of the tropical epoch in Europe, 121.—Geikie on geological time and the glacial period, 122.

107. *Humboldt's Views on Geological Exhalations of Carbonic Acid Gas.*—Of carbon in a gaseous form there no longer exists in the north hemisphere so large a proportion as mingled with the extinct European tropical atmosphere. On this important branch of our subject Humboldt expresses his views as follows:—"Exhalations of carbonic acid are, even in our days, to be considered as the most important of all gaseous emanations with respect to their number and the amount of their effusion. We see in Germany, in the deep valleys of the Eifel, in the neighbourhood of the Lake of Laach, in the crater-like valley of the Wehr, and in Western Bohemia, exhalations of carbonic acid gas manifest themselves as the last efforts of volcanic activity in or near the foci of an

earlier world. In those earlier periods, when a higher terrestrial temperature existed, and when a number of great fissures still remained unfilled, the processes we have described acted more powerfully, and carbonic acid gas and hot steam were mixed in larger quantities in the atmosphere; from whence it follows, as Adolph Brongniart has ingeniously shown, that the primitive vegetable world must have exhibited almost everywhere, and independently of geographical position, the most luxuriant abundance and the fullest development of organism. In these constantly warm and damp atmospheric strata, saturated with carbonic acid gas, vegetation must have attained a degree of vital activity, and derived the superabundance of nutrition necessary to furnish materials for the formation of the beds of lignite (coal), constituting the inexhaustible means on which are based the physical power and prosperity of nations. Such masses are distributed in basins over certain parts of Europe, occurring in large quantities in the British Islands, in Belgium, in France, in the provinces of the Lower Rhine, and in Upper Silesia. At the same primitive period of universal volcanic activity those enormous quantities of carbon must also have escaped from the earth which are contained in limestone rocks, and which, if separated from oxygen and reduced to a solid form, would constitute about the eighth part of the absolute bulk of these mountain-masses. That portion of the carbon which was not taken up by the alkaline earths, but remained mixed with the atmosphere as carbonic acid, was gradually consumed by the vegetation of the earlier stages of the world, so that the atmosphere, after being purified by the processes of vegetable life, only retained the small quantity that it now possesses, and which is not injurious to the present organisation of animal life." *

108. *Carboniferous Period in Europe ante-Tropical.*—In stating that there are no geological data to show that a temperate flora existed in Europe prior to its tropical era—which would have been the case according to the theory of a former

* Humboldt's 'Cosmos.'

extension of the torrid zone herein advanced--it should be understood as applying to a flora botanically analogous to that which now exists. This statement must be qualified by referring to the geological data from the fossil remains of the carboniferous epoch, which exhibit proofs of a vegetation existing before the tropical era of Europe, partaking in some measure of a temperate flora, but still not of a purely tropical character. That flora may be designated semi-tropical, inasmuch as its living congeners in Australia are found within the Tropic of Capricorn, and as far south as 40° of latitude; but the plants are so sensitive of cold that a sharp frost kills them, and even giant trees will perish it snow remains any length of time on the ground. These are gum-trees (*Eucalypti*), pine trees (*Araucaria*), arborescent ferns (*Dicksonia*), and sheack trees (*Casuarina*), which are analogous to the extinct vegetation of the coal formation, from their highly carbonic structure. As pointed out by Humboldt in the foregoing extract, the atmosphere at this period was highly charged with carbonic acid gas, which was absorbed by the luxuriant vegetation, the remains of which form the immense coal-fields to which Great Britain owes so much of its material prosperity. "The existence of such enormous quantities of coal itself bears witness to the extent of vegetation during the epoch of its production." And the amount of carbon extracted from the atmosphere aided materially in altering its chemical condition, which, as we shall see in the third part of this work on "The Air," changed the foliage of the trees from an evergreen to a deciduous condition. Therefore, be it remarked that previous to the tropical era in Europe there existed a semi-temperate flora, differing in character from what now exists, but analogous to what is found in the south temperate zone. Moreover, it was at this epoch that animals of a marsupial character, similar to the Australian kangaroo, leapt through the coverts of the carboniferous forests; and though these interesting animals roam over the tropics of their native country, yet are they abundant in its coldest latitudes.

109. *Absorption of Carbonic Acid Gas by the Coal-Formation.*—Without going further into geological data on this point, it is abundantly evident that, prior to the era of palms and cycadaceæ flourishing under the rays of a vertical sun, there was a period when plants of a comparatively temperate nature existed. This fact supports the theory advanced as to the gradual extension of the torrid zone before it became contracted to its present limits. There is also evidence that this carboniferous epoch lasted for such a space of time that the greater number of species became extinct before the dawn of the tropical era in Europe. Now this extinction of species did not result so much from the increase of heat as the decrease of carbonic acid gas in the atmosphere, on which the vegetation depended for its support. It is a botanical fact, proved by experiment, that ferns grow more rapidly and with a more woody texture in a factitious atmosphere highly charged with carbonic acid gas than they do in the ordinary air; also that pines, ferns, and shrubs, growing in craters of extinct volcanoes where this gas is ejected from crevices, flourish with greater luxuriance than at other localities in these mountains, where less carbon exists in a gaseous form. Hence it has been concluded that, during the carboniferous era in Europe, the gigantic tree-ferns, the *calamites*, *lepidodendra*, *sigillaria*, and other plants whose fossil-remains are so abundant in the coal-measures, were supported in their growth by the atmosphere being more highly charged with carbonic acid gas than at present. When this was reduced by absorption into the lignite from these dense forests they diminished in abundance, while the larger species became extinct, leaving only the fern-brake and mare's-tail, with their diminutive congeners, in our ponds and thickets at the present day, as vestiges of a colossal semi-temperate vegetation, anterior to the tropical era in Europe.

110. *This Period isolated from subsequent Transition Periods.*—On this point Humboldt remarks, in discussing the influence of reaction from the interior of our planet on the exterior, as not being "limited to inorganic nature alone.

It is highly probable that in an earlier world more powerful emanations of carbonic acid gas, blended with the atmosphere, must have increased the assimilation of carbon in vegetables, and that an inexhaustible supply of combustible matter (lignites and carboniferous formations) must have been thus buried in the upper strata of the earth by the revolutions attending the destruction of the vast tracts of forest." Thus the formation of our coal-deposits, so especially beneficial to the inhabitants of Great Britain, in time exhausted the gaseous element, or rather reduced it to an infinitesimal proportion of the atmosphere, such as exists at the present period. That this process of extinction of species was gradual, there are abundant data to show; while the duration of this remarkable epoch would appear to have been comparatively limited. Moreover, on the sections of strata forming the crust of the earth, it appears prominently in a succession of black-bands that have no counterpart above or below. We conclude, therefore, that it was a period in the world's history when the first flora of the north temperate zones enjoyed only a comparatively brief sojourn on the newly-upheaved lands of the north hemisphere, and the imperfect seasons of the epoch merged somewhat rapidly into the tropical era.

111. *Probable Extension of the Tropics during the Carboniferous Era.*—Assuming, as already taken for granted, that this change in the organic epochs was the result of an expansion of the torrid zone, it becomes interesting to inquire what were the degrees of obliquity of the ecliptic at the commencement and termination of the carboniferous era. If we take the latitudes of Australia and New Zealand as existing examples of that epoch, the tropic would then have extended to between 28° and 35° of latitude—as these may be called the middle latitudes of the gigantic conifers and arborescent ferns of those regions. Here the objection may be raised, that this bare assumption is not supported by astronomical computations showing that the angle of inclination of the earth's axis ever reached the minimum degree men-

tioned. Truly so; but if we look beyond the terrestrial orbit we shall find some of the planets with angles of inclination in their axes, and consequently tropical zones, much greater than the maximum, even the highest we have named, of 45° as a possible extension to the extinct tropical zone. This part of our subject will be carefully examined in the next chapter treating of the planetary seasons.

112. *General View of Epochs according to Tropical Extension, Maximum, and Diminution.*—Admitting, meanwhile, the general principle of this theory, the question involved in the last remark concerning transition periods of the tropical epoch in its decline, demands our attention, as to whether the world rested at its greatest obliquity of the ecliptic when the volcanic forces, lessening their activity in the north hemisphere, began to increase in the south. On this point geology furnishes ample data in the lower and upper secondary formations, when time was divided into epochs of immense duration, before the world reached the climax of its tropical existence. This we consider occurred at the commencement of the older tertiary formation, during the eocene period, when the expanded torrid zone showed symptoms of contraction as the obliquity of the ecliptic began to diminish. The following appears a rough sketch of the progress, maturity, and decline of the tropical history of our planet as revealed by geology: There are three grand epochs—the palæozoic, secondary, and tertiary—each being subdivided into several periods when the preceding genera and species were extinguished, and then succeeded by new forms of creation. In the palæozoic series we see a gradual scale of development, from the most ancient forms of organised beings, the remains of which are abundant in the Silurian rocks, up to the Permian system containing the fossil remains of vertebrata. In the secondary formation the higher classes of animals common to tropical regions increase in genera and species until they reach their most colossal dimensions. At the beginning of the tertiary formation the fauna and flora of Europe is still tropical; but as they pass through the miocene, plio-

cene, and pleistocene periods, there is a gradual decline from tropical forms to a temperate fauna and flora, such as now exist. Applying these epochs to our theory, the palæozoic would correspond with the increase of obliquity of the ecliptic, the secondary formation with its maximum, and the tertiary formation with its diminution and the origin of the seasons.

113. *The Extinct Organic World compared to the Rise and Fall of the Roman Empire.*—From what we have advanced in the foregoing chapters, it will be seen that nature in all her transcendental operations, whether in the interior of our planet, or in its movements among other celestial bodies in the universal cosmos, proceeds with gradual and measured pace towards the development of any physical structure or its phenomena. Hence, in tracing the decline of the tropical era in Europe and the rise of the temperate epoch, we find geological data which indicate a gradual extinction of the one blended with the origin of the other. Like the rise and fall of the Roman empire, we observe the disappearing of organic provinces one by one, and of the gigantic species of animals in those once tropical realms where they ruled with imperial sway. As the legions of Rome conquered that empire, so a universal torrid zone prevailed, sending forth its armies of invulnerable reptiles and mammalia to conquer and subdue the wide tropical world; so also do we now see the genial lands of the seasons broken up into many kingdoms of animals and plants, like the several monarchies of Europe, flourishing each in its own dominions, where once the laws of the Roman empire reigned supreme. And as the architectural relics of ancient Greece and Rome show the grandeur and extent of that extinct civilisation, so do the colossal remains imbedded in the fossiliferous rocks of the transition periods illustrate the gigantic organisms of the extinct organic world that succumbed to the encroachments of the frigid and temperate zones.

114. *Migration of Animals and Extinction of Plants in Transition Periods.*—As a rule, all animals indigenous to

warm regions will migrate towards the equator should their native clime become so cold that the temperature interferes with their enjoyment of life; and if they should be so geographically situated that they are prevented from migrating, the increasing lowness of temperature will ultimately extinguish the race. Moreover, while a decrease in temperature leads to the extinction of a species presenting tropical forms of animal life, it also affects plants of a tropical character, and as they have not the power of locomotion, they are the first to be extirpated by a frigid or rigorous clime. Thus, on the decline of the tropical era, the vegetable food of herbivorous animals became extinguished, and as their carcasses served as food for carnivorous beasts and birds, the entire organic world of that era in Europe was annihilated. Hence we find at the close of the eocene period—the first of the tertiary formations—that in the British Isles the general character of the fauna and flora was tropical; but, with one or two exceptions, all the species became extinct, and do not range to formations either above or below. Not only were the giant forms of that era extinguished in the middle latitudes of the north hemisphere, but those of analogous character and dimensions now inhabiting the tropics are all more or less specifically distinct from their eocene progenitors—showing thereby other organic changes in the atmosphere and vegetation from those of temperature, which will be further alluded to in the third part treating of "The Air."

115. *Miocene Period.*—The next period named by geologists is the miocene, as exemplified in the coralline crag of the British Isles, composed of marine calcareous sands, limestone bands, and greenish marls. "The coralline crag abounds in shells and zoophytes. Above 340 species of mollusca have been collected in it, of which 73 are living British species. . . . The general character of the fauna of this epoch is Lusitanian (*i.e.*, like that of the Spanish peninsula). Zoophytes abound, including many southern genera." * At this stage in the physical history of the world it may be said that

* Professor Edward Forbes, in Johnston's 'Physical Atlas.'

the seasons commenced their career, and the winter though short was sharp, cooling the air and the water, causing the migration of birds, beasts, and fishes to the south at its rigorous approach. At first their places were not supplied by the higher classes of animals in the water, and the land would appear to have been deserted as compared with the numbers of its previous occupants, while the succulent vegetation perished in the cold blast. From the geological remains of this period the fructifying powers of nature appeared to have been circumscribed in their action. She seems to have commenced *de novo* in engendering the lower forms of marine creatures with functions and organs adapted to the altered temperature of the sea, and raising small but hardy plants to resist the rigours of a winter season.

116. *Pliocene and Pleistocene Periods.*—The miocene period was succeeded by the pliocene, when there were changes in the genera and species of animals and plants advancing in organic structure, but adapted to the continued lowering of temperature. This new creation of organisms capable of resisting increasing cold evidently reached its climax at the close of the deposition of the newer tertiary formations—what geologists term the pleistocene period when ice abounded throughout Europe to a greater extent than at the present day; and it is evident that the seas, if not the climate, of that period reached a temperature as low as that on the confines of the arctic circle. "The fossils found in the British marine pleistocene are chiefly remains of mollusca. They are all either living British species now chiefly found within the Celtic region, or such as, still living within our area, are only abundant in the boreal region; or such as are extinct in our seas, but still survive in the arctic regions or on the coasts of boreal America. A few southern forms, which do not now range to our seas, accompany them. The fauna of the glacial beds, including the mammaliferous crag, consists of above 170 species of marine animals, chiefly mollusca. In the fresh-water beds many extinct mammals occur."*

* Professor Edward Forbes.

117. *Advent of the Glacial Period difficult of Explanation.*—Looking to the theory of a gradual diminution in the atmospheric temperature from tropical to temperate in Europe, as set forth in this chapter, the occurrence of a glacial period between these climatic changes will appear at first sight subversive of such a doctrine. It seems contrary to the laws of nature that the period of arctic frigidity which prevailed through the glacial period should intervene between extreme and moderate degrees of heat. We shall, however, endeavour to show that this apparently exceptional period to the general law may be accounted for on solid grounds, in accordance with our theory.

118. *Forbes's Description of Glacial Phenomena in the Alps.* The evidences of the glacial period are numerous, and consist of indications existing in countries where no glacier exists at present, as in Scotland, and their former extension where they now exist, as in Switzerland. "The immediate neighbourhoods of most of the glaciers of the Alps afford unequivocal traces of their having been much more extended at periods anterior to history than even in the present day. . . . Vast moraines, or heaps of transported blocks and gravel, at considerable distances (a mile or more) in advance of the present bounds of ice, have been admitted on all hands, at least since the time of De Saussure, to attest this fact. Those most frequently quoted are the old moraine of Lavanchi, near Chamouni, belonging to the Glacier des Bois; the moraine of the Glacier of Rossboden, on the Simplon; and that of the Glacier of the Rhone. Admitting these, we find it impossible to draw a line between them and other moraines in or near the mouths of valleys whose heads are still occupied by glaciers; and this evidence is strengthened if we observe the same character of the rocky surfaces which the friction of glaciers undoubtedly produces—namely, perfectly smooth, rounded, dome-like forms (called *roches moutonnées* by De Saussure), grooves, and striæ in the direction in which ice must be moved; and in some cases a fine even-polished surface, such as is produced by continued attrition, but

never by crystallisation. Such are the phenomena seen near St Gervais in Savoy, where (as already mentioned) the travelled blocks and gravel of Mont Blanc may be continuously traced from the neighbourhood of Sallenches (and probably much farther) up to the existing moraines of the Glacier of Bionassay, and others in the same direction. . . . But, so much being admitted, it seems impossible to stop here. The continuity of moraines and the effects of attrition seem to connect the vast blocks of Monthey, in the valley of the Rhone below St Maurice, with the undoubted glacier deposits of the valleys of Trient and Ferret; and the blocks of Monthey cannot reasonably have any origin ascribed to them which must not be extended by precise parallelism of circumstances to the innumerable forests of primitive boulders which once strewed the whole plain of Lower Switzerland, and which, reaching the Jura Mountains (formed entirely of limestone), has left an imposing memorial of its existence in the vast belt of granitic masses, but slightly worn or rounded, which lie along the face of that chain facing the Alps, at a height of 800 feet above the plain of Switzerland and the Lake of Neufchatel. Startling and improbable as such an origin must be admitted to be at first sight, it is found, upon examination, that every hypothesis yet proposed to explain so important and striking a geological phenomena is pressed with not less formidable difficulties." *

119. *Application of our Theory to account for the Glacial Period.*—Further evidence need not be adduced to show that a period existed, subsequent to the tropical epoch in Europe, when intense cold prevailed, such as now exists during winter in the arctic regions. It does not follow, however, that a corresponding frigidity of climate continued all the year round; it is quite compatible with natural phenomena, where extremes of heat and cold exist on continents, to find an approach to an arctic winter and a tropical summer in the same latitudes. This will be more fully alluded to in citing the north of China as an example of these extremes

* James D. Forbes, in Johnston's 'Physical Atlas.'

of temperature, where the thermometer falls to 10° and 15° below zero in winter, and the sea is frozen in the Gulf of Pee-che-lee many miles from the shore; while in summer the thermometer rises to from 130° to 140° in the sun, and from 110° to 115° in the shade, with palm-trees and bamboos flourishing luxuriantly. It requires only an extension of this fact to account for the glacial period—that is, a colder winter than now prevails in Europe, and a hotter summer. Such, we contend, existed when the obliquity of the ecliptic reached a diminution of 30°, or six and a half degrees greater than it is now. Assuming that the obliquity had obtained a maximum of 45° at the tropical epoch, one-half of the north hemisphere—and the south also—received the perpendicular rays of the sun, so that the land and the sea absorbed such an intense degree of heat during six months of the year, that sufficient caloric radiated in the atmosphere to prevent any accumulation of ice and snow in winter. In all probability an intense humidity prevailed, such as we find in tropical latitudes at the present day. But when the diminution reached 30° the distribution of heat and cold over high latitudes was reversed; only one third received the vertical rays of the sun, while the other two-thirds were subject to a short but severe winter, from the sun being so much lower at its meridian altitude during that solstice. At that period, also, the spring and autumn were scarcely defined, and the year was divided into a hot and cold season, each probably intense in degree throughout European latitudes as in North China or in Canada. During the cold season glaciers were formed more rapidly and extensively on the Alps than at present; and these would move quicker, in consequence of the greater heat dissolving them, carrying boulders and gravel along with them. Hence the moraines are larger, the grooves are deeper, and the surface of the rocks finer polished by the ancient swift-moving glaciers, than by those that now exist, when the heats of summer are tempered by the spring, and the cold of winter by the autumn. On this principle there will be a gradual cooling of summer throughout Europe, and a

more genial temperature in winter, as the obliquity of the ecliptic diminishes.

120. *Its Duration computed by Rate of Diminution of the Ecliptic.*—For the reasons given, we have assumed that the glacial period commenced when the obliquity of the ecliptic diminished from its maximum point of 45° to an angle of 30°. On the same hypothesis we assume that it continued during a further reduction of five degrees, until the angle reached 25°, comprising a period of time—computed from the basis formerly given, of one degree in eight thousand years—equivalent to 40,000 years. It must be understood, however, that there was a gradual approach to that frigid era in Europe, as we find a slow departure from it, in the existence still of glaciers in Alpine regions, though not at lower altitudes. The term specified may be considered, therefore, as applying to the time during which the glacial period existed in its greatest intensity of cold, as exemplified by the evidence of ancient moraines and boulders.

121. *The Glacial Period extinguished the Fauna and Flora of the Tropical Epoch.*—At this stage of our inquiry it is important to observe that the rigorous winters of the glacial period effectually extinguished the tropical vegetation and animals previously existing in Europe, and hence the great diversity of the living fauna and flora from the fossil remains which prove the existence of that extinct epoch. Had there been no such sudden transition from a torrid to a frigid climate, it is just possible that the botany and zoology of Europe would have presented genera and species more nearly allied to those of the tropics than they do. As it is, the leading characteristics of our indigenous plants and animals approach more nearly the arctic types than the tropic. There is evidence also to show that during the glacial period the organic forms of creation in the British Isles, more especially in Scotland, partook of an arctic character, and these are gradually disappearing with the present epoch, which may be appropriately designated *the epoch of the seasons.*

122. *Geikie on Geological Time and the Glacial Period.*—

On this head Mr Geikie, F.R.S., Director of the Government Geological Survey of Scotland, made some excellent remarks in a lecture "On Geological Time." He directed attention to the facts that the present flora of the British Isles was the result of a long series of geographical and botanical changes; and that the shells in the seas had gone through a similar series of changes—our present marine fauna showing that there had been great changes in the inhabitants of the seas within a very recent geological period. Some species of arctic shells still lingered in the depths of some of our western sea-lochs; and it was clear that at the time the arctic flora prevailed on the surface of the land, arctic fauna inhabited the seas; and that, just as the arctic flora had been driven to the mountains by the increasing mildness of the climate, so the arctic fauna had been driven, by the same cause, step by step to the depths of the seas, and there they would die out, just as the arctic plants would do on the tops of the mountains. All these changes, he showed, had taken place within the glacial period, and yet no shell, so far as was known, had become extinct. From other evidence it was known that the interval which had elapsed since the glacial period had been very long. Now, if so vast a period had produced so little change in the organic world, how enormous must be the periods embraced in the geological record, when whole dynasties of plants and animals have passed away! Whatever our theory as to the origin of species might be, we must admit, he argued, that their extinction cannot but be an extremely slow process. Yet thousands of species and genera had appeared and disappeared since the introduction of life, and during the passing away of the ages presented by the geological record. But that geological record was confessedly very imperfect. We have therefore to deal not merely with the periods of which it contains some memorial, but likewise with those of which no chronicle remains. Hence intervals of time which were not represented in our rocks by sedimentary fossiliferous strata might perhaps be even vaster than the time which was so

recorded. . . . The geological record affords no data for computing the lengths of its periods in years. If, however, it contained traces of any great cosmical event, it might be possible to arrive at the date of such an event; for the astronomical periods were not vague like those of geology, but could be stated in years. It had long been a belief among thoughtful geologists, that if any accurate data of this kind were to be found, it must be by the labours of the astronomer, rather than the geologist.

123. *Concluding Remarks on computing Geological Time.*—We have already expressed our opinion to the same effect, not only regarding the computation of geological time by astronomical events, but the application generally of planetary phenomena to terrestrial geology, and, *vice versâ*, terrestrial phenomena to planetary geology. In the next chapter this mode of testing the value of our theory of extended and contracted tropics will be fully exemplified by the varied phenomena of the planetary seasons. Meanwhile we again recommend the astronomical rate of diminution in the obliquity of the ecliptic, which produces an annual observable decrease registered by astronomers, as a basis for calculating geological time. To show that a tangible formula may be arrived at, we shall reduce the average decrease to an ordinary degree of historical time and terrestrial contraction of the tropics. This average rate of diminution has been fixed by astronomers at 45 seconds of latitude in a century, which is equivalent to about half a geographical mile of contraction in the perpendicular rays of the sun towards the equatorial line. If we reduce this by British statute measurement it gives a diminution of 3080 feet in 100 years, or about 30 feet per annum. At this rate the deep well at Syene, in ancient Egypt, would no longer be illuminated at the bottom, for the perpendicular rays of the sun have moved 11¼ miles south of that city, where Eratosthenes first measured the width of the torrid zone two thousand years ago. Could we trace the geological changes that have occurred during that period, we might then compute the time astronomically since the tropi-

cal epoch reigned in Europe by an extension of the torrid zone to the latitude of London, or even to the Shetland Isles, where fossil remains of tropical vegetation and animals are found—say in 60° N. lat., where the sun's rays might have been perpendicular 290,400 years ago. That such a phenomenon was not impossible will be seen in the planetary evidences of even greater extension of the tropics illustrated in the next chapter.

Moreover, there are bright appearances about the poles of Mars which Herschel ascribes to the reflection of light from mountains of ice and snow accumulated in those regions. "The analogy between Mars and the earth," he remarks, "is by far the greatest in the whole solar system. Their diurnal motion is nearly the same, the obliquity of their respective ecliptics not very different; of all the superior planets the distance of Mars from the sun is by far the nearest alike to that of the earth; nor will the length of the martial year appear very different from what we enjoy when compared to the surprising duration of the years of Jupiter, Saturn, and the Georgium Sidus (now named Uranus). If we then find that the globe we inhabit has its polar region frozen and covered with mountains of ice and snow, that only partly melt when alternately exposed to the sun, I may well be permitted to surmise that the same causes may probably have the same effect on the globe of Mars; that the bright polar spots are owing to the vivid reflection of light from frozen regions, and that the reduction of those spots is to be ascribed to their being exposed to the sun."

129. *The Fall and Thaw of Snow seen in the Polar Region of Mars, and the Extremes of Heat and Cold very decided.*—Recent observations of this most interesting planet confirm the views of Herschel and earlier astronomers; and as the instruments in observatories are becoming more powerful and perfect, we may look forward to fresh discoveries regarding the planetary seasons. Of the latest, M. Guillemin furnishes a concise account in his admirable work on popular astronomy, entitled 'The Heavens,' in which he has the following remarks on the seasons of Mars:—"Thus, from the earth we can watch the formation of the polar ice, and the fall and thaw of the snows on the surface of a neighbouring planet; in a word, all the vicissitudes of heat and cold which distinguish the seasons of winter and spring, autumn and winter. The succession of these changes is now so well established, that astronomers can predict approximately the form, relative size, and position of the northern and southern snow-zones.

We have said that the two white spots are not of the same extent either during their respective winters or summers. The snowy cap of the southern hemisphere varies within much greater limits than that of the opposite pole; it is much more extensive during the winter season, and it diminishes during the summer to such an extent that it does not occupy more than the fifth part of the superficies of the snowy spot of the northern pole. This difference is easily explained by the great inclination of the axis of the planet to the plane of its orbit, and by the fact that the southern pole is turned towards the sun when Mars is nearly at its smallest distance from the focus of light and heat. The summer-time, on the other hand, of the northern hemisphere, occurs at the epoch of its greatest distance. The quantities of heat received by the globe of Mars at these two opposite points of its orbit vary in the ratio of seven to five. In truth, these differences of temperature are partly compensated in the course of a revolution; but the extremes of heat and cold are still very decided."

130. *Mars possesses an Atmosphere, and its Climate is subject to Terrific Storms and Hurricanes.*—"We have seen that Mars presents the most curious analogies with the earth; and it is probable that to the inhabitants of Venus our planet presents the same appearances that Mars does to us. Like the poles of Mars, the poles of the earth are covered with snow and ice: it is also our southern pole that is most frost-bound, and for the same astronomical reasons, by the congelation of the aqueous vapour. Lastly, the points of greatest cold on Mars, as on the earth, do not coincide with the poles of rotation. . . . If snow falls in Mars, it is because water is there evaporated by heat; hence, the water must be spread on the surface under the form of clouds, which condense sometimes in a liquid state in the form of rain, sometimes as snowy crystallizations. Thus Mars certainly possesses an atmosphere of aqueous vapour. But we see too distinctly the prominent spots of the disc, not to be certain of an atmosphere analogous to our own, the pressure of which, by

counterbalancing the expansion of the aqueous vapour, prevents it from usurping all the surface. We have already said that the more luminous borders of the disc allow us to infer the existence of a cloud-bearing atmosphere, which effaces by its brightness the dark spots when the rotation brings them towards the limb. The meteorology of Mars is, then, to a great extent known. It presents, we repeat, the greatest analogies with the meteorology of our earth. But at the same time notable differences distinguish them. As Professor Phillips has remarked, the considerable periodical exchange of moisture which is made between the two hemispheres, especially between the two poles, must give rise to hurricanes and storms, of the violence of which we can form no idea; while the melting of the snows over such large areas must produce terrible inundations."

131. *Seasons of Mars double the Duration of ours.* "We have seen that Mars turns on its axis in about 24⅔ hours. Thus the duration of its movement of rotation exceeds that of our sidereal day by 41 minutes. Mars accomplishes an entire revolution round the sun in 687 of our terrestrial days. But the year of Mars only contains 669⅔ of its own sidereal days; and as the number of solar days is always less by one than that of the rotations, the year of Mars in reality is composed of 668⅔ of its own solar days, which gives, for the duration of one of those days, 24 hours, 39 minutes, 35 seconds. Thus a whole day of Mars exceeds one of our days by 39 minutes 35 seconds. The difference is not very perceptible. Besides, the inclination of the axis of rotation to the plane of the ecliptic is nearly the same as that of the axis of the earth. It follows that in the course of a year Mars presents its various regions to the sun nearly like our globe, so that the length of the days and nights, in the different latitudes, is distributed in the same manner. The extreme zones, torrid and frigid, are a little more extended, proportionally, which consequently reduces the surface of the temperate zones. But it must not be forgotten that this is a favourable circumstance, at least for the tropical regions, since the solar

light and heat arrive at the planet with an intensity much less than on our globe. Between Mars and the earth, however, there is an important distinction, and it lies in the difference between the terrestrial and martial seasons. In the northern hemisphere of the planet, the 668 days of its year are divided as follows:—spring lasts 191 days 8 hours, summer 181 days, autumn 149 days 8 hours, and winter 147 days. But the summer seasons of the northern hemisphere are the winter seasons of the southern hemisphere, whence it follows that the spring and summer, taken together, last 76 days longer in the northern hemisphere than in the southern one." *

132. *Seasons of Saturn of thirty times longer Duration than ours.*—In that extraordinary planet, Saturn, astronomers have ascertained the inclination of its axis to be 26° 49′, or less than that of Mars and greater than that of the earth.

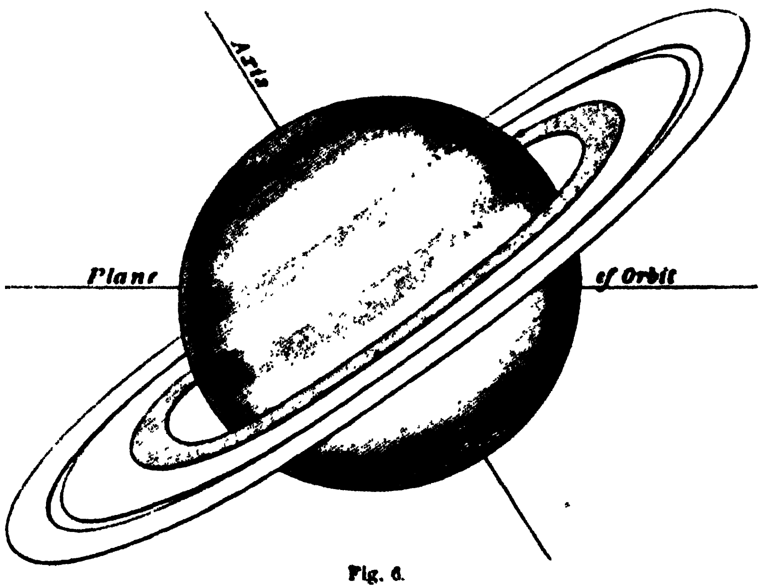


Fig. 6.

SATURN,—Showing the Inclination of its Axis.

"Owing to the considerable inclination of the axis to the plane of the orbit, Saturn presents to the sun sometimes one and sometimes the other of its poles of rotation. For the

* 'The Heavens.' By A. Guillemin.

same place on its surface, the altitude of the sun above the horizon is still more variable than on the earth; but if we wish to form an idea of the change of temperature due to this cause, it is important to remark that the altitude of which we speak varies thirty times less rapidly than with us. Each of Saturn's seasons lasts more than seven of our years, and there is nearly fifteen years' interval between the autumn and spring equinoxes, and between the summer and winter solstices. But we should have but an incomplete idea of the phenomena presented by the days, nights, and seasons of Saturn, if we did not take into account the modifications produced in these elements by the existence of the annular appendages by which this magnificent planet is surrounded, and by the presence on the horizon of the eight satellites which escort it in its long revolution of thirty years." *

133. *Great Inclination of Axis in Venus.*—Although the greater inclination of the axis of rotation in Mars and Saturn serves to illustrate the variability of the angles presented by each planet, still these are not sufficient to furnish data for concluding that the tropical zone might extend to middle latitudes. This fact is fully demonstrated in the very considerable inclination of the axis of rotation in the planet Venus. According to Lockyer, this is computed to be 49° 58', or nearly $2\frac{1}{2}$ times that of the earth. Other astronomers consider it to be much greater, as represented by M. Guillemin in a diagram of the planet, here copied. On this point he remarks, that "the nearly circular form of its orbit gives a nearly equal length to the four seasons, and the light and the heat of the sun are distributed with a like constancy. But that which establishes a marked difference between the terrestrial seasons and climates, and those of the planet we are exploring, is the great inclination of the axis of rotation to the plane of its orbit. Fig. 7 shows the position of the planet at one of its solstices, at the commencement of the summer of the hemisphere which presents its pole to the sun. At the winter solstice Venus occupies a diametrically opposite

* 'The Heavens.' By A. Guillemin.

position. It follows that the polar regions undergo alternately the torrid temperature of summer and the prolonged cold of winter. At the equator, the sun then hardly rises above the horizon. Towards the equinoxes, on the contrary,

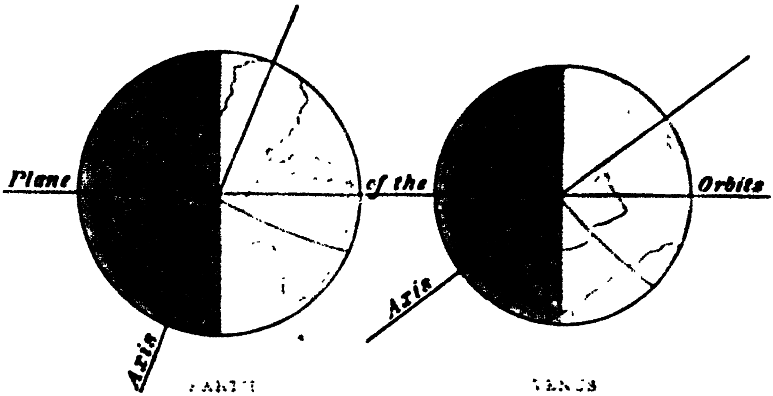


Fig. 7.

the regions nearest the equator are exposed to the heat of the sun, the intensity of which is nearly double the intensity of the solar heat on our globe. Perhaps a very dense, cloudy atmosphere, constantly charged with vapours arising from the heat, envelops the globe of Venus, and thus moderates the rigour of its opposite seasons. A fact which gives to this hypothesis a certain degree of truth, is the observation of the transit of Venus over the sun in 1761, when a nebulous ring seemed to surround the black disc of the body."

134. *Angle computed at about* 50°.—"Venus, the most beautiful object in the heavens, is about 7700 English miles in diameter, and placed at the distance of sixty-eight millions of miles from the sun. Although the oscillations of this planet are considerably greater than those of Mercury, and she is seldom invisible, yet, on account of the uniform brilliancy of her disc, it is extremely difficult to ascertain the period of her rotation. Dominic Cassini, after having long fruitlessly attempted to discover any object on her surface so well defined as to enable him to follow its motions, at length, in 1667, perceived a bright part, distant from the southern

horn a little more than a fourth part of the diameter of the disc, and near the eastern edge. By continuing his observations on this spot, Cassini concluded the rotation of Venus to be performed in about 23 hours . . . The question of the rotation of Venus was finally settled by Schroeter, who found it to be performed in about 23 hours, 21 minutes, 19 seconds. Each of the observers found the inclination of the axis of rotation to the axis of the ecliptic to be very considerable. Subsequent observations have fixed the angle of inclination at 49° 58′, and there is reason to doubt the value of this element."

135. *Mountains of great Height at South Pole.*—"Schroeter's observations on this planet were principally directed to a mountain situated near the southern horn. The line which joins the extremities of the horns is always a diameter; and the horns of the crescent of a perfect sphere ought to be sharp and pointed. Schroeter remarked that this was not always the case with regard to the horns of Mercury and Venus. The northern horn of the latter always presented the pointed form, but the southern occasionally appeared rounded or obtuse—a circumstance which indicated that the shadow of a mountain covered the part;" while "he remarked a luminous point, which he supposed to be the summit of another mountain, illuminated by the sun after he had ceased to be visible to the rest of that hemisphere." *

136. *Equipoise of Venus revolving in Space greatly disturbed.*—From these observations of this interesting planet we learn that there are mountains of conspicuous elevation on its surface, and of such enormous magnitude in proportion to its spherical dimensions that they enable our astronomers to determine the period of its revolution. And what is worthy of remark, this prominent protuberance of land is situated in the south hemisphere of Venus, without any apparent equivalent in its northern hemisphere; showing a disproportion in the continental masses of that planet similar to, if not greater than, what exists on the earth. It is also observable that this preponderance is in the opposite hemisphere to what

* Art. "Astronomy," 'Encyclopædia Britannica.'

is found in our planet. Nevertheless, the same law prevails, and we can conceive that if the first volcanic forces in the interior of the earth were directed to South America instead of its northern sister, besides Asia and Europe, the counterbalancing power would have been the reverse to what it is, and the same as in Venus. Looking, therefore, at this beautiful object in the heavens through a powerful telescope, we see a globe poised in space, but thrown out of its equilibrium, between the axis of rotation and the plane of its orbit, to an extent more than twice the displacement of the earth's ecliptic; consequently, the differences of her days and seasons must be very great.

137. *Mercury has comparatively the highest Mountains in the Planetary System.*—In like manner, it has been discovered that the planet Mercury exhibits phenomena of a similar nature, thereby supporting the theory of an extended torrid zone having at one time prevailed on the earth; only that from physical causes, the observations are not so determinate as those of the planet Venus. "Mercury is about 3140 English miles in diameter, and his mean distance from the sun about thirty-seven millions of miles. On account of his smallness and brilliancy, it is extremely difficult to find any spot on his disc so distinctly marked as to afford the means of determining his rotation. Besides, by reason of his proximity to the sun, an observation of a spot, if made in the evening, can scarcely be well begun before the planet sets; or, if in the morning, before the increasing twilight renders the spot invisible. Hence it is only possible to observe daily a very small arc of a small circle; and if the spot reappears on the succeeding day, it is doubtful whether the arc it has passed over exhibits the whole motion, or if one or more circumferences ought to be added. By an attentive observation of the variations of the phases of Mercury, Schroeter has, however, remarked that he revolves about his axis in the space of 24 hours, 5 minutes, 30 seconds. M. Harding discovered in 1801 an obscure streak on the southern hemisphere of the planet, the observations of which, together with

those of a spot discovered by Schroeter, gave the same period of rotation." * From the results of that eminent astronomer's researches on Mercury we also learn that his equator, like that of Venus, "is very considerably inclined to his orbit, and the differences of his days and seasons must consequently be very great;" and "there are mountains on his surface which cast very long shadows, and of which the height bears a greater proportion to the diameter of the planet than those of the earth, the moon, or even of Venus. The height of Chimborazo is $\frac{1}{1571}$ of the radius of the earth; one of the mountains in the moon has been estimated at $\frac{1}{214}$ of her radius; the highest in Venus at $\frac{1}{144}$; and one in Mercury at $\frac{1}{126}$. The highest mountains are in the southern hemisphere, which is also the case in respect of Venus. There are no observations to prove decisively whether Mercury is surrounded by an atmosphere."†

138. *Guillemin on Planetary Phenomena.*—On the recent observations and conjectures on the physical constitution of this planet, M. Guillemin has the following remarks and data:—"We now know the movement of Mercury round the sun, the time of its revolution, its distances from the sun and the earth, and, lastly, its dimensions in diameter, in surface, and in volume. It only remains now to speak of what is known of its physical condition. The facts that science has succeeded in gathering on this curious and important point of the monography of the planets ought to present a lively interest to us all, by reason of the likeness or contrast which each of these worlds possesses to our own. The manner in which light and heat are distributed on the surfaces of the planetary bodies; the succession of their days, nights, and seasons; the existence or the want of an atmosphere like ours; lastly, the surface-markings that the telescope has permitted us to observe on their surfaces,—are so many valuable particulars which enable us to make the most probable conjectures on the organisation of the living beings which doubtless people them. Supported by such positive data, imagination can then boldly launch into the field of conjecture.

* Art. "Astronomy," 'Encyclopædia Britannica.' † Ibid.

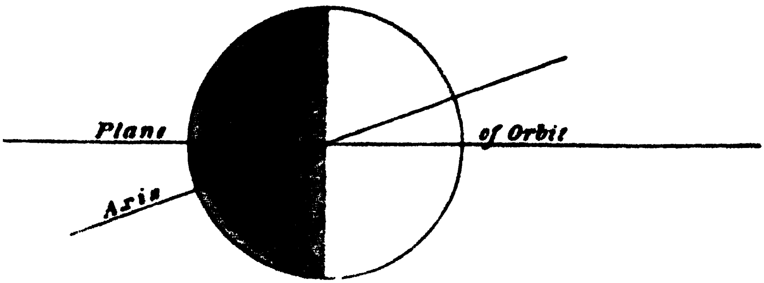
139. *Mercury receives Heat and Light from the Sun seven Times more intense than the Earth.*—"The intensity of the light which Mercury receives from the sun, at its mean distance, is nearly seven times as great as that with which our globe is illuminated under the same conditions of distance. It is not then surprising that the ancients gave Mercury the epithet of 'Twinkler.' This is not all. The laws governing the propagation of radiant heat are the same as those of light. Mercury then receives seven times more heat than the earth, or, more properly, a heat the intensity of which is in the mean seven times as great. To judge by the impression which the light-rays make on our eyes, seeing that we cannot bear their dazzling brightness without pain, and, again, by that which they make on our body when it is subject to their influence, the inhabitants of Mercury should be exceedingly uncomfortable. But are they formed like us? and have their senses the same degree of impressionability? We know not. Variations of temperature are also disagreeable to us. In this respect, again, we must own that the inhabitants of Mercury have more to suffer than we. Owing to the planet's elongated orbit, we have seen that it sometimes recedes from, and sometimes approaches, the sun, and that the difference between the extreme distances amounts to fifteen millions of miles. So that whilst at aphelion the intensity of the luminous and heat-rays is no more than four times and a-half that of the rays received by the earth; at perihelion, on the contrary, it rises to more than ten times the same quantity. Lastly, and this adds still more to the contrasts of temperature, the variations occur in a period of time less than a quarter of one of our terrestrial years. Presently we shall see that the seasons present still greater anomalies.

140. *Its Claims to an Atmosphere not fully determined.*—"We must not forget, however, that one circumstance may modify all this to an extent sufficient to render the conditions of vegetable and animal life in Mercury either similar to our own, or more different still. This circumstance is the existence or absence of a gaseous or vaporous envelope—in a word,

of an atmosphere. Has Mercury then an atmosphere? According to many astronomers, Mercury presented such an appearance in its transit across the solar disc in 1799. Instead of a black round spot, perfectly clear and well defined, there was seen all round the disc of the planet a circular band less luminous than the rest of the surface of the sun, forming a sort of nebulous ring. It was thence inferred that there existed a very high and dense atmosphere. Recent observers have not seen anything like it. But, on the other hand, they have remarked in the phases of the planet, that the line of separation of the light and shade, which astronomers call the *terminator*, is never very decided, so that the breadth of the luminous part seemed diminished. 'Hence,' say Beer and Mädler, 'we must conclude that Mercury has a pretty sensible atmosphere.' If this be so, we can form an idea of the modifications which a somewhat dense atmosphere would induce in the intensity of the light and heat, by comparing the days when, on our earth, the sky is clear and without clouds—when the sun darts its rays on the surface without obstacle—with the dark and dull days when the clouds completely hide him from us. The density of the atmospheric envelope, we see, can strikingly change the effects of solar radiation. Let us compare, for instance, the temperature of one of our valleys with that of the mountain summits which surround it. It is like passing from summer to the cold of winter—from the burning heat of July to the frost of November; and yet the sun shines alike on the mountains and on the valley. Finally, the chemical composition of the atmosphere of Mercury, the nature of the gases of which it is formed, and which are perhaps very different from the nitrogen and oxygen of our own air, are also features which may influence the climate of the planet; concerning these matters we have no data. Let us confine ourselves, then, to describe the astronomical phenomena, of which the influence is incontestible.

141. *No Temperate Seasons, from its extreme Angle of Axial Inclination.*—"In the first place, let us consider the length of the day. Mercury turns on its axis in 24 hours and 5½ min-

utes, and his year comprises $87\frac{2}{3}$ of these sidereal rotations. The number of his solar days in this period is therefore $86\frac{2}{3}$, whence results as the length of one of them 24 hours and 54 seconds. This is nearly the length of one of our own solar days, so that the organised beings of the two planets have the



Mercury at one of its Solstices showing the Inclination of the Axis of Rotation at the approximate angle of 75°

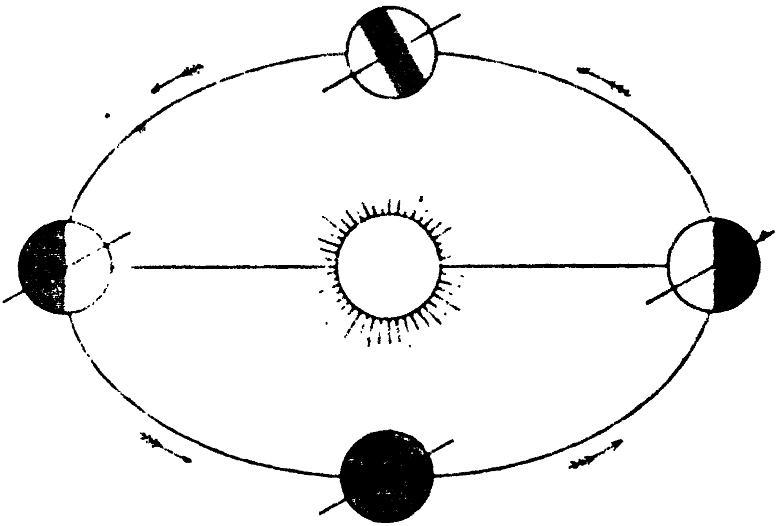


Fig. 8.

Orbit of Mercury showing perpendicular Solar rays at lat. 75°.

same periods of light and darkness, of activity and repose. But the relative length of the days and nights in the course of the entire year is much more variable than on the earth.

owing to the great inclination of the axis of Mercury to the plane of its orbit. Fig. 8 shows, according to old observers, at what angle Mercury presents itself to the sun at the commencement of each of its seasons. Very extensive zones around the pole enjoy at one season, during their summer, continuous day; at another, during their winter, they are plunged in profound darkness. It is only during a short period, and near the planet's equinoxes, that these zones see light and darkness succeed in the interval of the same day. The glacial and torrid zones are not distinct on Mercury, and temperate climates do not exist, or rather their zones change their character twice during each revolution. The equatorial regions alone have the advantage of possessing all the year day and night, light and darkness, and of experiencing heat during the day, cold and calm during the night. It is true, however, that if the sun towards the equinoxes rises as far as the zenith, it descends nearly to the horizon in the extreme seasons. We have said above, that the orbit of Mercury is very elongated, or, in astronomical language, its eccentricity is considerable. It results that the seasons in Mercury are of very unequal duration, and seeing that, according as we consider the northern or the southern hemispheres, the spring and the summer of the one are the autumn and winter of the other, a like inequality should exist between the extreme temperatures of the two hemispheres."

142. *Inclination of Axis more than Treble that of the Earth.*—The inclination of the axis of rotation in Mercury has not been sufficiently determined to give its true value. It was Schroeter, at the end of the last century, who deduced the inclination given in the diagram, from observing some dark bands on its disc, which he considered as an equatorial zone. At an approximate calculation the obliquity of the ecliptic in Mercury is not far short of 75°, which, if it be correct, would exceed that of Venus by one-third, and more than treble that of the earth—an obliquity which would not only subject Europe to the influence of a tropical clime, but is equivalent to a torrid zone stretching on each side of the equator beyond

the present limits of the arctic and antarctic circles on our earth.

143. *Mercury Typical of the Earth during the Tropical Epoch in Europe.*—In these two brilliant examples of our planetary system, we have not only periods of diurnal rotation corresponding to that of our own planet, but obliquities of the ecliptic far exceeding that of the earth at the present time, and considerably beyond the bounds of the theory of expansion and contraction herein expounded, and to which we have attributed our tropical epoch in Europe. It has been suggested that the maximum of the earth's torrid zone in that era did not exceed an inclination of 45°, while in Mercury it is considered to be about 75°. Here, therefore, are data that would justify an extension of the obliquity of the earth's ecliptic at one time to 50° or even 60°, which would fully account for the long epochs during the earlier existence of the world, when those monster animals—the iguanodon, megalosaurus, mastodon, labyrinthodon, ichthyosaurus, plesiosaurus, and their congeners—were brought into being amidst a gigantic vegetation that could have flourished only under an intensely tropical clime, where now we find their fossil remains in temperate and even frigid regions. When we consider the acute angle at which Mercury rotates in its orbit round the sun, exposing its circumpolar regions to a degree of heat equal to, if not greater than we find in the temperate zones of the earth, we cannot imagine these to be regions of ice and snow like ours, while we may easily surmise that the middle latitudes between the poles and the equator are subject to a heat more intense than that within our tropics. And as there is evidence that Mercury is enveloped in an atmosphere supposed to be denser than ours, we can understand how, in all probability, that planet is now, over three-fourths of its surface, sweltering under tropical heats, that bring forth the monsters of its forests and waters—the giants of its organised creation—such as reigned supreme on this earth before the advent of the glacial period.

144. *Table of the various Degrees of Planetary Inclination*

of Axis.—Let us now glance at the various degrees of inclination each planet we have described presents between its equatorial plane and the plane of its orbit—including that of our own planet—commencing at the smallest obliquity. According to the latest astronomical calculations these are as follows :—

Jupiter, ...	3° 4′ 0″
Earth, ...	23° 27′ 24″
Saturn, ...	26° 49′ 0″
Mars, ...	28° 51′ 0″
Venus, ...	49° 58′ 0″
Mercury, ...	(?) 75° 0′ 0″

145. *Problem involved open to Solution by our Theory.*—In contemplating the planetary sphere from this point of view, we fail to perceive any general law which regulates the inclination of the axis of rotation in each planet, in relation to its distance from the sun or the perturbations of the planets on each other. While astronomers have taken the greatest pains to observe the phenomena as materially assisting to unfold the physical constitution of the planets, based upon the physical phenomena of our own, they have not ventured to account for the great disparity between the slight inclination of Jupiter and the wide displacement of the equatorial planes of Venus and Mercury from the planes of their orbits. Hence the subject may be considered an open question, to be dealt with upon geological principles. Here, then, we find certain data bearing upon our theory, which point to some law inherent in each planet, that where the inclination is greatest, as in Venus and Mercury, the protuberances of the land are highest above the sphere of rotation; and where the angle is smallest, as in Jupiter, there is no observable elevation above the sphere of revolution, while the low degree of density (·0227) suggests a liquid surface on that planet. On these data are we not justified in deducing the hypothesis that the inclination is caused by the internal volcanic forces acting unequally on the external hemispheres in upheaving solid matter?

146. *Extraordinary Phenomena of Climate and Seasons in the Moon.*—This view of the general question would be incomplete if we omitted to point out the infinitesimal inclination of the moon's axis to the ecliptic, which is determined by astronomers at 1° 30′ 10″, or less than half the least inclination of the superior planets. Combining this with the lengthy diurnal rotation, annual revolution in its orbit, and other phenomena, the climate and seasons of our satellite are more extraordinary than those of any of the planets. "During about fifteen days the sun pours his rays without any cloudy curtain or aërial current to temper them. To this temperature, more intense even than that of our torrid zone. succeeds an intense cold, which a night of fifteen days' length renders more glacial than that of our polar winters. It is true, that during the day the radiation of the solar heat into space again is not prevented. We must conclude, therefore, that the climates of the various regions of the moon have a certain analogy with those of our Alpine regions, seeing that the depression of the temperature, and the reverberation of the intense light there, become insupportable by the continuity of their action. There are, properly speaking, no seasons in the moon. The slight inclination of its axis of rotation maintains the sun at a nearly constant inclination in each latitude. But whilst in the equatorial regions the radiant body scarcely leaves the zenith, at the middle of the day, in the polar regions, it scarcely rises above the horizon. The polar mountains enjoy perpetual day. One can understand, also, that the inclination of the sun to the lunar surface, variable according to the latitudes, can never have on the moon the same importance as on the earth, since the rays, whether luminous or calorific, are transmitted directly to the surface without having to traverse atmospheric strata of unequal thickness. The revolution of our satellite is effected with variable velocity, whilst its movement of rotation is uniform. Hence it follows that of 1000 parts of its surface 569 are visible and 431 constantly hidden from us."*

* 'The Heavens.' By A. Guillemin.

147. *Astronomers have overlooked the importance of Planetary Variations of Axis.*—The variations in the obliquities of the planetary ecliptics are a subject of great interest in our researches regarding the laws that control the solar system, and one that appears not to have commanded the attention of astronomers which its importance deserves. Content with the suggestion that these phenomena have arisen from external perturbations in the planetary system, they have ignored all inquiry into the existence of internal action in each planet as the probable cause of this general displacement from the perpendicular axis of their orbits. If this obliquity had been at a uniform angle throughout the planetary sphere, then we could have supposed that some great general law, emanating from the sun by virtue of his attraction, originated and controlled it. But when we find the divergence ranging in round numbers from 3° in Jupiter to 75° in Mercury, with the medium angles of 23° on the earth and 28° in Mars, we are justified in inferring that it supports the theory of internal causes for the obliquity of ecliptics generally; the result of local disturbances in the physical condition of planets, differing from ordinary celestial perturbations which affect their annual rotation round the sun. In the orbital disturbances affecting planets, we can understand how they may diverge from their accustomed path as they attract each other by the way, while rushing through space with tremendous velocity, singly or in satellite groups. Here all obey the central law of gravitation towards the sun, yet susceptible to a small degree of each other's attractive power, and that of erratic comets visiting the fervid heat and light of the supreme central globe of fire and gravitation.

148. *The Solar System compared to a Central State and its Provinces.*—Through the light thrown upon the operations of the universal law of gravitation by the immortal Newton, it is comparatively a simple matter to comprehend slight aberrations in the planetary manifestations of the principle involved. It is otherwise, however, when we come to consider the disturbing causes that have driven the earth and the

other planets from their equilibrium, where aberration from a fixed angle of axis is the rule, and uniformity the exception. To make a familiar comparison, it might be said that the planets represent subsidiary states within the empire of the sun, where they are subject to general laws for the mutual conservation of the whole. But each planet, like a separate state under a union, has an inherent power within itself to form its own laws of self-government, provided they are not contrary to the spirit of the general constitution. Thus we may consider that though the earth is obedient to the great luminary from whence it derives all its vital power, if not its primary existence, yet by its internal energy it has raised the fabric of its own greatness as the abode of plants and animals, without which it would have been a fluid sphere, with an äeriform envelope, comparatively inert and lifeless. In this sense the general laws are astronomical, and the special laws geological; at the same time the latter are dependent on the former.

149. *The Planetary Range of Obliquity supports our Theory of Tropical Extension to* 60°.—Now that we have cited planetary examples of tropical zones of wider dimensions than our own, and shown that the obliquity of the ecliptic which produces this phenomenon on our planet is diminishing, these data seem almost sufficient to sustain our inference that the tropical regions of the earth extended formerly into the present temperate zones, even had we no organic fossil remains to prove the existence of an extinct tropical fauna and flora. But when we combine the astronomical with the geological evidences, the case appears almost conclusive. As previously observed, the only doubtful point of the question is, to what maximum extent the angle of obliquity expanded the tropics? We have ventured to place it at 45°, a parallel of latitude passing through the south of Europe, and 10° below the central latitudes of the British Isles. Now, as we have seen that some of the most gigantic and essentially tropical forms of plants and animals are found in the fossiliferous rocks of Scotland as well as England—which Miller so

graphically describes—there is good evidence that the tropic may have reached the highest latitudes of Great Britain, even to the Shetland Isles, bordering on the parallel of 60° N. Coupling these geological evidences with the astronomical observations that the planet Mercury probably revolves on its polar axis at an angle of 75° to the plane of its orbit, there is nothing contrary to the order of nature in the hypothesis that the earth, during that epoch, had a torrid zone 120° in width, or an obliquity of 60° in her ecliptic. This would not only account for the wonderful organic remains in the secondary and tertiary formations of geologists, found in northern Europe, but would extend the period of the tropical epoch to something approaching their calculations of geological time, taking the diminution of the obliquity of the ecliptic as the basis of computation. In a former chapter of this division of our subject, this diminution was given at the rate of one degree in eight thousand years, showing a lapse of 172,000 years since the tropical era existed in its intensity in Europe. According to the same computation, with 60° as the angle of obliquity, the lapse of time would be increased to 292,000 years. All things considered, and as far as the finite views of man can enable him to penetrate into the infinite realms of the past, the actual expansion of the torrid zone probably reached the maximum of 60°, and its duration nearly that of three thousand centuries, before it attained the present limit of 23° 30′, irrespective of the period of its augmentation, or that during which, in all probability, it remained at its maximum.

150. *Speculative Views that might arise from the Theory of an extended Tropical Zone.*—Instead of limiting our computations on this point of time, the speculative philosopher might step in here with arguments based on our theory which would extend the primary augmentation of axial inclination on our planet until it reached an angle of 90°, when the polar regions would exchange places with the equator, altering the circle of the seasons. He might point to the fossil remains of tropical plants in Greenland as only to be accounted for in this manner; and as showing that, if

we could examine the fossiliferous strata of the circumpolar regions, it is possible that similar evidence would be found of a tropical climate having once existed there. On the other hand, he might account for the remarkable evidence discovered by Agassiz in Brazil, that glaciers once deposited boulders and moraines in latitudes within the limits of the present tropical zone at the sea-level. It might be argued, if the displacement reached a right angle, we can imagine the frigidity of the winter season near the equator, when the sun scarcely appeared above the horizon, causing the formation of glaciers at a comparatively low altitude; while, at the same time, the summers in high latitudes would be sufficiently hot to support tropical vegetation. Pursuing his speculative arguments further, he might hold that there was no evidence to the contrary why the earth having reached its culminating degree of axial inclination at 90°, the same forces which set it in motion, continuing their motive power, drove the north polar axis beyond the equatorial plane into the southern celestial hemisphere until the terrestrial hemispheres were ultimately reversed in relation to the planetary plane of the ecliptic. So that if sentient beings lived on the British Isles in those ages, they would have beheld in the heavens the constellation of the Southern Cross above the horizon where now the Great Bear is in the ascendant. In support of this extension of the tropic into the arctic regions, the speculative philosopher might find astronomical evidence in the extreme inclination assigned by living astronomers to the axis of the planet Uranus. According to Lockyer, as given in his translation of 'The Heavens,' by Guillemin, this is represented as being equal to a right angle of displacement. Hence it may be argued, that instead of the earth diminishing its tropical zone by contraction of a maximum extension, it is possible that it is making a revolution from the zenith to the nadir of the celestial sphere. And if we can bring this hypothesis to bear upon the law of universal gravitation, or as being in accordance with the laws that rule the movements of the heavenly bodies, we can

conceive that the earth may have reversed its polar axis during the great geological epochs. Also that the disparity in the inclination of the planetary axes may be accounted for by the different stages they have arrived at in *polar rotation*, according to a law perhaps as universal as those laws which regulate their axial and orbital rotation. As the annual rotation in regard to the earth takes 365 times longer to perform its circuit than the time accomplished by a diurnal revolution, so might there be a polar rotation having a boundless space of time for its revolutions, in which the epochs of the geological record describe the vast circle of its seasons—a carboniferous spring, an eocene summer, a pliocene autumn, and a glacial winter. Thus computing the rate at one degree in eight thousand years—as given by astronomers to the diminution of the tropical zone—it would take 2,880,000 years to make one complete polar revolution. Here is a speculative basis of calculating geological time that might serve to clear up, by astronomical calculations, all the inexplicable phenomena of sedimentary deposits, tropical and frigid epochs, origin and extinction of species, and the numerous unexplained anomalies of geology.

151. *Comets present no indications of possessing fixed Axes of Rotation.*—There yet remains a class of celestial bodies belonging to the solar system to be noticed, which, as far as human knowledge goes, are exceptional as regards the law of fixed axial rotation. These are comets, whose erratic movements and eccentric orbits have hitherto baffled astronomers to assign to determinate laws. In referring to them briefly it is not necessary to enter into the questions as to the probable nature of cometary substance, or the cause of their wondrous luminous tails that from time to time illuminate the heavens in their transit from the realms of outer darkness into the fervid heat and light of the sun. Suffice it to say, that astronomers agree that, in the largest comets observed, each has a nucleus more brilliant than its surroundings, which, if stripped from it, would in all probability present a spherical disc having the ordinary aspect of

the superior planets, varying like them in size and degree of brilliancy. Of these nuclei, the most remarkable of which we have any authentic scientific description is that of the celebrated comet of 1680, figured in Lemonnier's 'Histoire Celeste.' The figure given there exhibits a nucleus or disc of a perfectly spherical form, as seen through a telescope. This disc is surrounded by what was concluded to be a cometic atmosphere. Above that was a sort of ring, wider at the summit and narrower towards the sides. "A *coma* or beard succeeds the ring, and lastly an immense train of luminous matter, somewhat less vivid than the nucleus."* Now, it must be observed, that although the bright centre in a comet presents the densest portion of its substance, yet it is stated on the best authority, that "the real nucleus has probably never been observed by any astronomer."† Be that as it may, the nuclei—whatever may be the nature of their substance—present a more perfectly spherical form than any of the planets; but, in consequence of the luminosity of the rarified substance considered to be their atmospheres, no astronomer has yet been able to observe any evidence of a comet possessing a fixed axis of revolution. In the absence of any positive data on this point, it may be advanced with scientific probability, that it is probably in consequence of not yet having acquired this law, that these erratic members of the solar system are so eccentric in their orbits. On the other hand, it may be said that the fixed law of axial revolution in the planets probably forms the basis of their concentric orbital rotation. Without this apparently subsidiary rotatory motion it is just possible that the superior rotation of a planet round the sun would otherwise approximate in eccentricity to the orbits of the comets. We have elsewhere started a supposititious case of what the consequences would be if the earth was a perfect sphere, equal in density at all points of latitude and longitude on its surface and in ratio of pressure towards the centre, when in all probability there would be no fixed axis of rotation at the poles, and the

* Art. "Astronomy," 'Encyclopædia Britannica.' † Ibid.

world might revolve without any determinate angle of diurnal revolution in its annual rotation, like a billiard-ball or a *round-shot, turning* over in all directions though maintaining its line of projectile motion. On this hypothesis may not the comets fly off at a tangent beyond the planetary sphere, because they have no fixed axes of revolution to keep them within a concentric orbit? This hypothesis of a very perplexing question in astronomy may be exemplified in a popular manner by comparing a planet to a whip-top, which revolves within a circumscribed sphere as long as it is kept in motion by flagellation; while the comet may be compared to a boy's marble, which, if whipped in the same manner, would roll over and over in a straight line, or might be more correctly described as performing a parabolic curve in its onward progress.

152. *Concluding Remarks on the Difference between internal and external Perturbations in the Planetary Sphere.*—From what has been said concerning the deviation of the heavenly bodies from a universal uniformity of revolution, we may with scientific propriety conclude that, as a rule, the pristine or normal condition of a planet revolving in its diurnal motion would give the angle of the axis of rotation at a right angle to the plane of its orbit, with which the equatorial plane would coincide. This may be considered as a necessary result of the universal law of gravitation where its primary influence has not been disturbed by secondary agencies. Any deviation from that fundamental principle of rotation is an exception to the rule, and must arise from the attractive power of planetary bodies on each other, or, as we have suggested, the action of the internal forces of each individual planet on itself. In the former case, we have evidence of perturbations causing the eccentricity of their orbits from the form of a perfect circle, and displacement of the planes of these orbits from that of the ecliptic; and, in the latter instance, internal forces affecting their equilibrium so as to incline their axes at various angles from the axes of their orbits. Here are, therefore, two distinct modes of displace-

ment from the normal movements of the planets—one from external, and one from internal causes. *The question involved* appears to us very simple, and requires no profound knowledge to understand, once it is admitted that the forces produced internally by heat exert an influence on the general motion of a planet. Hitherto such an element has not entered into the calculations of geometers, consequently we have no mathematical data to prove or disprove the hypothesis. We venture to hope that the subject may command the attention of those who are better able to furnish a satisfactory solution than we can lay claim to; and, whatever be the result, we shall be satisfied with having pointed out the problem to be solved.

CHAPTER VIII.

EPOCH OF THE SEASONS.

Introductory remarks on this practical branch of the subject, 153.—Direct or secondary causes that produce the seasons properly defined, 154.—Astronomical definition of the apparent cause of the seasons, 155.—Familiar illustration of apparent motion, 156.—Astronomical description and diagram of the seasons, 157.—Diminution of obliquity overlooked by writers on the subject, 158.—Popular remarks concerning changes in the seasons, 159.—Hypothesis of obliquity of the ecliptic not conclusive, 160.—This astronomical problem open to solution by geology, 161.—The question of displacement considered astronomically, 162.—Geological inferences may be in harmony with astronomical truths, 163.—Practical solution of this question a matter of public importance, 164.—Popular division of the four seasons in the almanacs, 165.—General characteristics of the seasons and calendar months, 166.—Antiquity of the study has not exhausted the subject, 167.—Poetical fancies of happy lands where perpetual summer reigns, 168.—The seasons, their fauna and flora the result of contracted energy, 169.—Natural history of this epoch the most perfect in structure, 170.—The seasons evidently of comparatively recent geological origin, 171.

153. *Introductory Remarks on this practical Branch of the Subject.*—From the realms of conjecture and the lifeless vestiges of the world's past organic history, we now come to an epoch of living evidences of its progress, full of animation and stirring events, when man first appeared on the stage of life; a period which may be appropriately termed *the epoch of the seasons.* In reviewing the preceding epochs through the dim and imperfect records of the past, as revealed by geology and astronomy, it is a continual groping in the dark to reach the smallest approximation to truth. Now, under the penetrating beams of the great luminary that vivifies the

planetary system, we behold the minutest changes in the external condition of our planet, from which we may deduce the secondary causes and effects that inaugurated the wondrous phenomena which physical geography lays open to us in the book of nature. But in appreciating the evidences of the present era and its origin, we must not disparage the vestiges of the past. Although the dumb witnesses of fossil geology are not so numerous and convincing in their evidence as those which the existing organic and inorganic worlds unfold, yet they should be valued accordingly, as the progenitors and types of living plants and animals, and the foundation of the fertile soil they inhabit. Like the dead languages—without which the living tongues of Europe would have had no utterance—these strange natural hieroglyphics on stratified rocks comprise the classics of geology, in which we read concerning the origin of the seasons as we now experience them. At the same time, as the development of the attendant phenomena was gradual, it will be necessary to refer briefly to the immediate causes of the seasons, as demonstrated by astronomers, in order to understand more clearly the changes which the climate of Europe has undergone since the tropical epoch; or, according to our theory, during the diminution of the tropical zones to their present limits.

154. *Direct or Secondary Causes producing the Seasons properly defined.*—The immediate causes that produce the phenomena of the seasons are described in two ways—the one by the real motions of the earth in its diurnal revolution and annual rotation in its orbit round the sun, and the other by the apparent movements of the sun, moon, planets, and stars over the celestial meridian. From the latter method of description being in accordance with the vicissitudes of the day, month, and year, as they roll on before our perceptive faculties, astronomers have taken the most elaborate care to demonstrate the apparent causes, while the real ones, best understood by our reflective faculties, are comparatively overlooked. This is purposely intended, as it would be a matter of extreme intricacy of expression, if not confusion of language, to

describe every position of the heavenly bodies in the ephemeris, in respect of their daily changes, by the complex movements of our planet. It is true that, for the purposes of navigation, the distances of the earth from the heavenly bodies are given in the nautical ephemeris according to their real position; but for general astronomical purposes their apparent movements are still held as the basis of describing the phenomena of the seasons. It is well, however, to remind the reader of the fact, that "All these movements, both those of rotation and translation round the sun, and those of nutation and precession, are effected simultaneously by the earth. The motion of our globe has often been compared, and with justice, to that of a top which, while turning on itself with great rapidity, and tracing on the surface which supports it a line which may be likened to its orbit, undergoes also a balancing of its axis of figure or rotation analogous to the oscillations of the earth. There is this difference, that the various movements of the earth are accomplished with mathematical regularity in periods relatively very long, and according to laws which allow us each instant to assign its true position in space." *

155. *Astronomical Definition of the apparent Causes of the Seasons.*—"In astronomy the seasons are considered as beginning respectively when the sun enters the signs Aries, Cancer, Capricorn, and Libra. Hence the spring season commences about the 21st of March, summer about the 22d of June, autumn about the 23d of September, and winter about the 23d of December." This is the stereotyped definition of the seasons which has obtained from the earliest observations of astronomers up to the present day; yet, as regards the sun entering these particular signs of the zodiac on or about the days and months enumerated, the calculations no longer hold good, in consequence of the precession of the equinoxes. That phenomenon has been already alluded to as being entirely different from the obliquity of the ecliptic, the diminution of which arises from the displacement of the

* 'The Heavens.' By M. Guillemin.

ecliptic itself; the procession of the equinoxes is, on the contrary, occasioned by the continual displacement of the terrestrial equator, through the combined action of the sun and moon on the mass of protuberant matter about the earth's equator. If the sun and moon moved in the plane of the equator, there would evidently be no precession. "In consequence of this regression of the equinoctial points, the sun's place among the zodiacal constellations at any given season of the year is now greatly different from what it was in remote ages. Some time prior to Hipparchus, the first points of Aries and Libra corresponded to the vernal and autumnal equinoxes; those of Cancer and Capricorn to the summer and winter solstices: at present these constellations have separated thirty degrees from the same points of the ecliptic. The vernal equinox now happens in the constellation Pisces, the summer solstice in Gemini, the autumn equinox in Virgo, and the winter solstice in Sagittarius. Astronomers, however, still count the signs from the vernal equinox, which, therefore, always corresponds to the first point of the *sign* of Aries. On this account it is necessary to distinguish carefully between the *signs* of the zodiac, which are fixed with regard to the equinoxes, and the *constellations*, which are movable with respect to those points." Of course it is presumed that the most superficial reader understands the apparent as distinguished from the real motion of the heavenly bodies in this instance, as it is the annual rotation of the earth round the sun which causes these changes, as the diurnal revolution on its axis is the cause of day and night.

156. *Familiar Illustration of apparent Motion.*—In the foregoing astronomical description we have regarded the sun as being apparently in motion round the earth; but the diurnal revolution of the celestial bodies may be equally well explained by supposing these motions to be only optical illusions; just as a person seated in a railway train in motion, passing another at rest, may be almost convinced that his carriage is stationary while the others are moving. "If we now consider the phenomena with reference to the earth, we

shall find that they may all be equally well explained on the hypothesis of the earth's motion, and the immobility of the sun. The most remarkable phenomenon connected with the annual revolution is the variation of the seasons; and in order to explain their cause it is only necessary to suppose that the earth, in describing its oblique orbit, always preserves its axis parallel to the same straight line."* But as mere description may fail to convey a correct idea of this well-ascertained phenomenon, it is necessary to demonstrate the fact by the usual astronomical diagrams.

157. *Astronomical Description and Diagram of the Seasons.*—"Let A, B, C, D, represent the earth in four different positions of its orbit, *n. s.* being its axis, and *n.* and *s.* being its north and south poles respectively. While the earth goes round the sun in the order of the letters A, B, C, D, its axis *n. s.* preserves its obliquity, and always continues parallel to

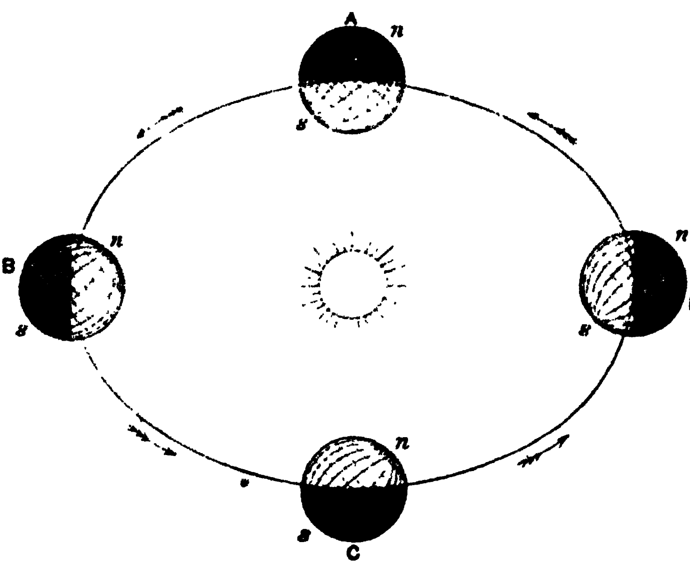


Fig. 9.

Diagram illustrating the phenomena of the Seasons.

its first direction. At C, the north pole inclines towards the sun, and brings all the northern places more into light than

* Art. "Astronomy," 'Encyclopædia Britannica.'

at any other season of the year. But when the earth is at A, the opposite point of the orbit, the north pole declines from the sun, and a less portion of the north hemisphere enjoys the blessings of his light and heat. At B and D the axis is perpendicular to the plane of the orbit, so that

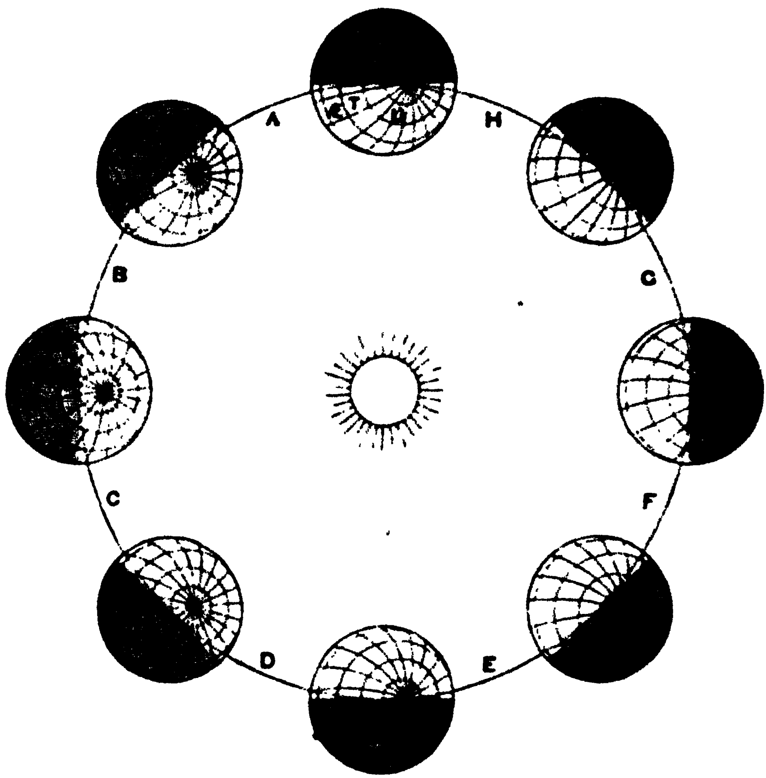


Fig. 10.
Diagram illustrating the phenomena of the Seasons.

the poles are situated in the boundaries of the illuminated hemisphere, and the sun, being directly over the equator, makes the days and nights equal at all places. These phenomena are illustrated in the second diagram (Fig. 10), which represents the situation of the north pole, with regard to the limits of illumination, in eight different positions of the orbit. In this figure, Æ is the terrestrial equator, T the tropic of Cancer, the dotted circle the parallel of London, U

the arctic or north polar circle, and above this is the north pole, where all the meridians or hour-circles meet. The spectator is supposed to be placed at the pole of the ecliptic. When the earth is at the beginning of Libra about the 20th March, the sun, as seen from the earth, appears at the beginning of Aries in the opposite part of the heavens, the north pole is just coming into light, and the sun is vertical to the equator, which, with all its parallels, is divided into two equal parts by the circle which forms the boundary between the dark and illuminated hemispheres, and therefore the days and nights are equal all over the earth. As the earth moves in the ecliptic according to the order of the letters A, B, C, D, &c., the north pole comes more and more into the light, and the days increase in length at all places north of the equator Æ. When the earth comes to the position between B and C, or the beginning of Capricorn, the sun, as seen from the earth, appears at the beginning of Cancer about the 21st of June; and the north pole of the earth inclines towards the sun, so as to bring into light all the north frigid zone, and more of each of the northern parallels of latitude in proportion as they are farther from the equator. As the earth advances from Capricorn towards Aries, and the sun appears to move from Cancer towards Libra, the north pole recedes from the light, which causes the days to decrease and the nights to increase in length, till the earth comes to the beginning of Aries, and then they are equal as before—the boundary of light and darkness cutting the equator and all its parallels equally. The north pole then goes into the dark, and does not emerge till the earth has completed a semi-revolution of its orbit, or from the 23d of September till the 20th of March. All these phenomena will be readily understood from the bare inspection of the diagram; and it will be perceived that what has been said of the northern hemisphere is equally true of the southern in a contrary sense—that is, at opposite seasons of the year."

158. *Diminution of Obliquity ignored by writers on the Seasons.*—With these and similar diagrams and descriptions, the phenomenon attending the remarkable displacement of the

equatorial plane from the orbit of the earth is dismissed by astronomers as fully explaining, in their estimation, the origin of the seasons. True, it is so, and they demonstrate clearly the immediate cause of the phenomenon, but almost ignore the important fact that this obliquity is diminishing, the investigation of which might lead to conclusions of still greater importance. A popular writer on the seasons, in treating of this subject, does not even consider the diminution as deserving of notice:—"We may further remark, that the earth's axis, though it changes its situation in space, changes its direction very little; so little and so slowly, indeed, that it has no traceable effect on the seasons, and therefore we may pass it by as too nice for our purpose."* Probably so, as far as one year's revolution of the earth round the sun is concerned; "and we may say that the earth performs its three hundred and sixty-five and a quarter rotations with its axis in the same position, and its plane of motion always the same; and this is the first and simplest branch of those motions of the earth which we must well understand, taken singly, before we can be prepared for understanding their joint effect." But may not that infinitesimal diminution in a year mount up, even in the course of a generation, or several generations, so as to have an observable effect upon the normal condition of each season, irrespective of the vast epochs of time considered in the previous sections of this work?

159. *Popular Remarks concerning Changes of the Seasons.*—It is a common remark among the inhabitants of the British Isles who are in positions to notice our proverbially changeable climate, that the seasons are not the same as they used to be, according to old meteorological registers; and even old people notice that the summers are colder and the winters not so severe as they remember them in their young days. These changes are accounted for by some meteorologists from the cultivation of the land, its drainage, the clearing away of forests, and other artificial causes; while some almanac manu-

* Robert Mudie—'Spring.'

facturers endeavour to show that the seasons change in cycles of fifty or sixty years, on which they ground their prognostications for the ensuing year. Without attaching greater weight to these opinions than all crude observations deserve, they indicate that there is some influence at work which alters the complexion and regularity of the seasons in the lapse of a generation, though the change is not noticeable in the year. May not these changes be attributable to the contraction of the torrid zone, caused by the decrease in the angle of the earth's orbit and the equatorial plane? At all events, the question is worth being investigated in this view, instead of "passing it by as too nice for our purpose."

160. *Hypothesis of Obliquity of the Ecliptic not conclusive.*—In like manner, astronomers furnish no conclusive explanation of the origin of the obliquity of the ecliptic, and rest satisfied with the hypothesis that it arises from the perturbations of certain planets. They say,—"Theory has shown that the cause of the displacement is the action of the planets, particularly of Jupiter and Venus, on the earth, by virtue of which the plane of the earth's orbit is drawn nearer to the planes of the orbits of these two planets." Upon the same grounds might it not be as logically advanced, that the obliquity of the ecliptic in Venus, which is more than double that of the earth, is caused by the influence of our planet's orbit upon hers? The astronomers further say:—"This, however, though by far the most considerable, is not the sole cause of the phenomenon; for theory also shows that a slight motion of the plane of the equator is produced by the attraction of the sun and moon, but so very minute that its effects will only become appreciable after a long series of ages." Granted that the sun and moon exercise a certain influence over the earth in producing the precession of the equinoxes, it does not follow that they affect this phenomenon of obliquity; while the earth itself is ignored as having direct share in creating and controlling this wonderful source of profit and pleasure to her industrious children dwelling within the latitudes influenced by the four seasons.

161. *This Astronomical Problem open to Solution by Geology.*—Let us even suppose that this obliquity was caused by the overwhelming attraction of the sun upon the north hemisphere, when that moiety of the earth presented its surface towards the parent centre of its gravitation during some early epoch of its convulsions, and at that part of its orbit marking its present summer solstice in Europe, and there would be more substantial grounds for the astronomical hypothesis than the planetary theory suggested. But the fact of the earth maintaining its oblique position when that hemisphere is at the winter solstice, or pointing away from the sun, distinctly illustrates the fact that solar attraction, however powerful in ruling the annual rotation of our planet, has little or no influence over the obliquity of its axis. And consequently, although the heat and light of the sun which fall upon the earth are the great source of organic phenomena produced by the four seasons, yet as to the origin of the seasons themselves, even astronomers do not attribute any influence to its gravitation. Neither do they attribute to any lunar attraction the cause of this phenomenon, although it is proved that the moon exercises great influence over the sea in producing the tides. If, then, the sun and moon have had no power in drawing the earth from its primary uniform equatorial plane and orbit, where shall we look for those perturbations which have produced and now control this wondrous phenomenon? It is advanced by astronomers, as we have seen, that the planets Venus and Jupiter have aided in altering the plane of the earth's orbit; but even in their hands the arguments are not conclusive. In the absence, therefore, of any incontrovertible astronomical data or calculations to prove the cause of this vital feature in the structure and functions of our planet, it is with the more confidence that we propound the geological theory, that the basis of the phenomena which we see manifested in the seasons emanated from the earth itself, irrespective of its position as a member of the planetary sphere. Like an independent state among the community of nations, possessing a constitution of its own,

yet consistent with the general balance of power, the earth holds the power of regulating her own sessional movements, though in her diurnal and annual rotation she is regulated by the universal law of gravitation—the sun being, as it were, the central power to which she is subservient.

162. *The Question of Displacement considered Astronomically.*—It must be observed once more that astronomers, in their researches respecting the diminution of the obliquity of the ecliptic, at first were uncertain whether the phenomenon is occasioned by the displacement of the plane of the ecliptic or that of the equator. By comparing modern with ancient observations they have come to the conclusion that the former is the cause, based on the following grounds:—"It is evident that, if the inclination of these two planes becomes less, the stars which are situated between them, particularly those situated near the solstitial colure (*i.e.*, the cardinal points of summer and winter), will appear to approach to that plane which changes its position; so that if the ecliptic is displaced, the latitudes of those stars will be diminished—or their declinations, if the displacement belongs to the equator. It was first observed by Tycho, and the observation has been confirmed by succeeding astronomers, that the latitudes of the southern stars situated near the solstitial colure—that is, of those stars whose longitudes are nearly 90°—have diminished upwards of 20′ since the time of Hipparchus and Ptolemy; while the latitudes of the northern stars have undergone a corresponding augmentation. From this fact it is proved that the diminution of the obliquity is occasioned by the displacement of the ecliptic."*

163. *Geological Inferences may be in Harmony with Astronomical Truths.*—At first sight this demonstration of the cause that produces the diminution of the obliquity would appear to stultify the arguments set forth in the preceding sections in support of our theory, which inclines to the contrary inference, that it was produced at first by the displacement of the equatorial plane from that of the ecliptic. We

* Art. "Astronomy," 'Encyclopædia Britannica.'

have endeavoured to show that in all probability the earth was driven from its normal equilibrium by internal forces, producing what should properly be called an *obliquity* of the axis instead of the planes. Having advanced this hypothesis with regard to the expansion of the angle of displacement, it does not follow that the principle would control the decrease of that angle. On the contrary, the affinity arising between the earth's orbit and its equatorial plane of revolution is another proof that these two planes were once in accord, and that they will again return to their original condition by virtue of the law of order that pervades the universe. Although it has been advanced that the counteracting forces in the south hemisphere, which arrested the maximum increase of the equatorial displacement caused by those previously acting within the northern half of the earth, were the immediate cause of diminution, it is not intended to prove that these subsequent influences were of equal power with the primary forces. Hence it may be inferred that the earth, having reached its greatest angle of obliquity by its internal agencies, has been aided by external influences in bringing the two planes, so separated, again into harmony with one another.

164. *A Practical Solution of this Question a Matter of Public Importance.*—Having so far demonstrated the apparent cause of this diminution, astronomers have rested in their calculations and observations at that point, leaving the great problem of obliquity, in our opinion, unsolved. With all due deference to their views and transmundane researches, they have not exhausted this field of inquiry, or brought their profundity of knowledge to bear upon the root of the question. In that sense its investigation should be continued by the aid of geologists and meteorologists, as appertaining more appropriately to the subjects of their study, in connection with the phenomena of the four seasons—a subject in which every one takes an interest, from the highest personage in the realm to the humblest labourer in the fields. The further prosecution of the inquiry becomes a point of practical importance to the community at large, as well as of scientific

investigation for the few who take an interest in its theoretical bearings. It involves the consideration of the *weather*, which exercises so much influence on the wealth and prosperity of Europe in general, and the British Isles in particular. Here we have a department of the Board of Trade charged specially to issue storm-warnings and forecasts of the weather for the guidance of the mariner, and in some respects the farmer. Hitherto these have been issued upon "a rule of thumb" plan, until at one period they were suspended as being frequently incorrect, the persons engaged in concocting them not basing their calculations on scientific data. Now, under the auspices of the Royal Society, a better system is in the course of adoption, and these prognostications may be the means of preventing many maritime disasters, and otherwise be of public utility. It is just possible that a consideration of the primary question as to the origin of the seasons and their variation, on the grounds set forth in this new theory, may assist the meteorologists in charge of the weather department of the Board of Trade in arriving at classified results, from the data furnished by their tables and registers, more in accordance with general principles than they are at present.

165. *Popular Division of the Four Seasons in the Almanacs.*—Besides the astronomical division of the seasons, which fixes the dates of their quarterly occurrence at the equinoxes and the solstices, every one knows that there is an ordinary division when spring is held to commence on the 1st of February, summer on the 1st of May, autumn on the 1st of August, and winter on the 1st of November. In this division the astronomical arrangement is considered as the culminating point of each season—such as midsummer, when the longest day happens on the 21st of June; midwinter, or the shortest day, on or about the 21st December; the vernal equinox about the 20th March; and the autumnal equinox on the 23d September. It is under this popular arrangement that the four seasons of the European year are best understood by the general reader, each with its sub-

division into three months, as set forth in the annual almanacs. With regard to these publications it must be observed that, as they are published in advance of the year indicated, all prognostications of weather must be taken as only approximate, sometimes not within days, at other times weeks, or even a month, of the date fixed regarding the occurrence or setting in of a season. Again, where particular degrees of heat, moisture, rain, &c., are indicated, the prognostications may prove correct on the sea-board, but erroneous inland; and what would apply to the British Isles in these details would not upon the Continent. In Great Britain itself we have an example of the variations of the seasons in different localities, which renders the gardener's calendar for England unsuitable for Scotland; while the farmers have earlier or later periods of seed-time and harvest, according as their crops are reared in the south or north latitudes of the island.

166. *General Characteristics of the Seasons and Calendar Months.*—Notwithstanding the variations of the seasons as they occur in comparatively adjacent localities, and their changeableness in respect of each locality in different years, there are general characteristics by which they are recognised as being distinct from each other. For example, spring is mild in temperature, and the season when plants begin to bud; summer is the hot season, when the flowers are in greatest bloom; autumn is a season of balmy airs, when fruits ripen and trees shed their leaves; and winter is the cold season, when vegetation lies dormant. Experience has shown, however, that there are exceptions in some years to these general characteristics; when a cold summer occurs, with snow in June or July—and a mild winter happens, when flowers bloom in the open air at Christmas. Seeing that the natural recurrence of each season, and its prevailing characteristics, are not fixed quantities in the order of nature, it is not surprising to find that the artificial division into calendar months fails to register the special phenomena allotted to each by almanac compilers. Yet, even in that division, there are certain characteristics in the economy of nature

observable throughout a series of years, which are applicable to any one particular month. For instance, January is the severest month of cold and frost; February the most cheerless month of the year in rain and snow; March is dry and windy; the fickle month of April is all showers and sunshine; the merry month of May is fresh and verdant; the leafy month of June is fragrant with the scent of flowers during its warm long days; July sets in with fervid heat and sunshine, when hay crops are garnered; August is the corn-harvest month, with clear cloudless skies; in September the weather is bracing; during October the leaves fall from the trees; November sets in with cold stormy weather; and December is the gloomiest month of the year. Some enthusiastic observers of the phenomena of the seasons and months go even further than the monthly subdivisions, and endeavour to show that each month may be divided into three parts, showing the variations between the beginning, middle, and the end. So might the variableness be traced even to each day, as exhibiting some difference from those preceding and following it. But it is not with these details that we have to deal in elucidating our subject; we shall endeavour to trace some general characteristics which distinguish the four seasons as they occur in Europe, in comparison with other regions, and these in relation to the extinct tropical and glacial seasons.

167. *The Antiquity of the Study has not exhausted the Subject.*—Unlike many other subjects of physical inquiry discussed by the ancients, which have been shelved in modern times as their errors have been corrected by the advancement of knowledge, the popular study of the seasons is not more interesting in this nineteenth century than it was before the Christian era throughout the Roman empire. Then, as now, it was the theme of the poet, and the topic of the day amongst the people; and we recognise in the names of the calendar months the titles of some of the Roman emperors who shed their imperial lustre upon the study during the Augustan age. From that period till now,

through succeeding ages of religious and political controversy, this topic alone has held its calm but firm hold upon the minds of the people, undisturbed by the conflicts of war or time. Hence it may be said that there is little or nothing new to be written about the four seasons, their phenomena and associations; but we are of opinion that something remains untold regarding their vicissitudes. In treating of this subject there seems to be a foregone conclusion among most writers—not excepting learned astronomers—that the seasons all at once leapt into existence, and that their origin is coeval with the creation of the world, or at all events with its pristine condition of land above the sea-level. When the farmer looks forward to the coming spring as the time for sowing his grain, to the summer when it will ripen, and to the autumn for his harvest, he considers the succession of these seasons, on which he depends for his subsistence, as things that must and ever will be, and that ever have been. When the gardener watches the seasons for the culture of his flowers, he calculates on their recurrence with something of a certainty akin to the return of day and night; and if his experiences have not travelled beyond Europe, he will smile incredulously if told that there are lands where the four seasons, quartering the escutcheon of the year in Europe, are condensed and bisected into a rainy and dry season in one region, or a short warm season and a long cold one in another. Those who live in a variable clime, such as Great Britain possesses, where the trimonthly seasons occur with tolerable regularity, and who have no experience of other regions where the divisions are unknown, become confirmed in the idea of their permanence and universality, and sing the praises of each recurring season as the bard of 'The Seasons,' Thomson, has sung, although nature rarely follows the flattering invitation:—

> "Come, gentle Spring! ethereal Mildness! come,
> And from the bosom of yon dropping cloud,
> While Music wakes around, veil'd in a shower
> Of shadowing roses, on our plains descend."

168. *Poetical Fancies of Happy Lands where Perpetual Summer reigns.*—Those who have lived in countries where the prolongation of summer on the one hand or winter on the other almost obliterates spring and autumn, look back with fond recollection to the land enjoying these vicissitudes of the weather to their fullest extent, even though that land has a rigorous or changeable climate. Imaginative poets revel in the glories of an eternal summer, and picture a paradise where no change of season or cold weather is known, as the happiest land for the human family. They sing of cloudless skies, the cerulean heavens above, the never-fading grove below, the continual hum of insects, and the constant fluttering and warbling of birds, as contributing to the *summum bonum* of human happiness. How different might be the reality, if we may judge from the sunny clime of Australia, where the bright blue sky has palled upon our senses, and we have longed to see a cloud on the horizon—where the evergreen forests soon appear monotonous to the eye, and we welcomed the sight of a deciduous tree; while the continual hum of insects and the chattering of birds became irksome, and their presence troublesome. Although that great south land is half within the southern temperate zone, yet the quarterly division of the seasons is not apparent, and the indigenous vegetation scarcely marks the changes from winter to summer, which specially distinguish the flora of the north temperate zone. Thus it is evident that the seasons, strictly speaking, are confined to a narrow belt of the globe compared with those regions where their distinctive character is obliterated, or blended into one climatic range.

169. *The Seasons, their Fauna and Flora the Result of Contracted Energy.*—This aspect and these phenomena of other climates beyond Europe it is not our purpose to discuss here, though there are points connected therewith that will demand our attention hereafter. What especially requires our consideration at present is the question, Whether the seasons have existed from all time or not? In reply it

may be said that there is abundant geological evidence to decide in the negative; and that they had a beginning in the history of our planet, with a gradual development throughout an immense course of time, like those other great changes in its physical condition which have been referred to. It must be observed, however, that in their progress from a primary state to their present condition, there has been a gradual breaking up of the tropical divisions of climate in Europe from which they originated. In the origin and development of extinct organic life we see an ascent in the scale of creation from the simplest forms of plants and animals to the more perfect in structure; and geology furnishes proofs that the inorganic solid matter of the earth progressed from a crude or plastic condition to a consolidated and crystalline state. Nature proceeded step by step in her march up the hill of developments during the *preparatory epochs* of the world's history, before she inaugurated the laws which now rule our terrestrial planet. And of these, the laws that control the seasons and arranged them originally into four divisions, it is evident, sprang from an advanced state of creation, and are the result of a previous condition of progressive development. It is abundantly evident from the vegetation and animated nature peculiar to the temperate regions where the seasons prevail, that these have not resulted from an expansion of nature's powers. On the contrary, everything connected therewith leads us to conclude that the seasons and their special fauna and flora were the result of a *contraction*, as it were, of a previous state of things; and also, that they could not exist as we see them now without having risen from an elementary condition, more rudimentary, more colossal, more prolific and intensely generative, than what now obtains in those countries where spring, summer, autumn, and winter are each in its turn a check upon the other in developing their species, as compared with the universal prolificness throughout the year in the tropical regions. In the growth of vegetation in Europe, for example, it is at times a struggle for existence,

even when aided by the efforts of man; in spring the bud is frequently nipped by the lingering frosts of winter, and in summer the blossom suddenly decays when a premature autumn comes on. How different in the tropics, where heat and moisture intensify the generative powers of plants, so that the efforts of man to keep vegetation within bounds are frequently abortive!

170. *Natural History of this Epoch the most Perfect in Structure.*—It would appear from these indications that the seasons and their natural history are the children of our common mother earth, begotten at an advanced period of her existence. So to speak, the comparatively humble weeds of the European thicket, the deciduous trees of the forest, the common animals that tread the greensward, and the modest birds that flutter through the grove, are all the children of her old age; while the progenitors of the brilliant and colossal creatures that inhabit the Indian jungle or the tropical waters are among the first-born. Before the modest elegantly-formed creatures of Europe were brought into being, she bore other fruits of her generative power, more gigantic, but less perfect in form and instinct: the early created plants and animals on the habitable globe were giants in physical aspect, rude in their structure, and low in their mental calibre. These perished, and out of their remains rose the lesser forms of organised life, which we now behold in Europe, augmented in brain and instinct, more peaceful in disposition, and more perfect in form and structure.

171. *The Seasons evidently of comparatively Recent Geological Origin.*—In tracing the progress of the torrid zone through its assumed expansion to the latitudes of 45° or 60° on each side of the equator, it was remarked, that although the latitudes of Europe must have passed through a temperate period such as now prevails, there is no evidence of a temperate fauna and flora having existed anterior to its tropical era. This is accounted for by the seasons recurring at an epoch while the earth was a barren region of rocks and

water, when vegetable or animal life had not yet appeared. Had this condition of things continued throughout successive ages up to the present time, it is not unscientific to conclude, that in all probability Europe would still have presented a barren aspect, sparsely covered with vegetation of a low order in its northern and middle latitudes, increasing in abundance on the confines of the tropics, and tenanted by such birds, beasts, and insects as became acclimatised to the colder regions north of the torrid zone, where they first had their existence. Heat, it is well known, is the great supporter and generator of animal and vegetable life, and it is chiefly derived from the sun. We find, therefore, that where the sun's rays are most intense and constant, there nature is most prolific in her productions. Consequently we naturally arrive at the conclusion, that the primary seats of organic creation must have been the hottest; and, as they spread towards cooler latitudes, subsidiary centres of organisation were formed under different physical conditions. Hence it required an intensely tropical climate to generate the primary progenitors of the indigenous flora and fauna of Europe, and these have risen, phœnix-like, from the ashes of an extinct tropical era; they are vegetable and animal kingdoms built out of the ruins of a primary organic empire, without which they never would have existed, or would have presented inferiority in structure. Viewed in this light, the seasons are of comparatively recent origin, and are among the latest efforts of nature to diversify the surface of the earth, and vary the atmospheric changes of the year.

CHAPTER IX.

EPOCH OF THE SEASONS.—*Continued.*

The ancient dogmas of stability superseded by the modern laws of change, § 172.—This epoch rose by necessity out of the transition periods, 173. —Animals decreased in size but increased in species during this epoch, 174.—Destructive animals decreased and harmless animals increased in species, 175.—Remarkable changes in the vegetable kingdom, 176.—Trees and shrubs changed their foliage from perennial to annual, 177.—Changes of the seasons best known from the flora of a country, 178.—The four seasons typical of the vast periods of geological time, 179.—Nature repeats itself in existing changes of extinct vitality, 180.—Migration of birds a vestige of the glacial period, 181.—Probability of the seasons having passed their climax, 182.—Difficulty of prognosticating the changes of the weather, 183.—The Duke of Buccleuch on the advantages of storm-signals, 184.

172. *The Ancient Dogmas of Stability superseded by the Modern Laws of Change.*—In ancient times it was a favourite dogma with the philosophers of Greece and Rome to uphold the stability of things in the physical world as evidence of the fundamental laws that rule the movements of the visible universe. The earth was placed immovably in the centre of all the systems, around which the crystal spheres of the several descriptions of heavenly bodies revolved, yet these—sun, moon, planets, and stars—were fixed in their transparent media, unalterable and eternal. Taking example from the supposed stability of the material order of things, the civilised nations of antiquity sought to establish laws in the moral world as permanent as those which seemed to prevail in the physical. Hence we read of the laws of the

Medes and Persians, which were considered unchangeable, and the appellation of the "eternal city" to the city of the Cæsars. Time has exploded these dogmas of stability; and in modern days the doctrine of change is the rule in both physical and moral philosophy. On the one hand, we see nations and governments altering their laws and improving their institutions progressively, so that, in the course of a few generations, the whole fabric of society is changed—old laws become obsolete, and a new order of things rules, according to the exigencies of the day. On the other hand, almost every year brings forth some new discovery in astronomy and geology, representing hitherto unknown changes in the condition and movements of the earth and heavenly bodies, from which principles are deduced proving that there is no stability in the universe, and that throughout past time there has been a continuous change in all things. In accordance with these principles we have referred to the inclination of the earth's axis, its extension and diminution, as an illustration of this instability of things. Hence, in reviewing the seasons and the monthly subdivisions of the year, there is one grand deduction to be made from the varied phenomena they present like an endless panorama before us, and that is, CHANGE. At whatever period of the year, or in whatever region of their influence, we behold their effects upon the physical world, on animate or inanimate objects; there is a constant change going on of *renovation and decay*, which alone marks any general principle in the laws that regulate their succession. All is evanescent in the never-ending scene, from the summer cloud that flits athwart the azure sky, to the snowy mantle that covers the ground in winter—from the tiny snowdrop that struggles into existence in spring, to the giant oak shedding its leaves in autumn. Everywhere and at all times the flag of the seasons is before us, inscribed with the everlasting insignia, "Change;" and the summer breeze and winter storm are continually ringing in our ears, "Change! change! eternal change!"

173. *This Epoch rose by necessity out of the Transition*

Periods.—From this we derive the theory that the seasons originated during a transition period, when nature was more active than usual in renovating the decay of a prior epoch, which reduced the species of the vegetable and animal kingdoms of the north temperate regions to their lowest numbers. There is abundant geological evidence to show that the glacial period not only extirpated the flora and fauna of the tropical era in Europe, but its frigid winters reduced the genera and species to an arctic minimum capable of resisting the inclemency of that season at its northern confines. Hence, when the gigantic animals and plants disappeared, they were succeeded by species diminutive compared to their progenitors. These, however, were not altogether new forms of creation. They appear to have been simply the primary forms modified in their organs and functions, as they became acclimatised to the altered temperature of the atmosphere and water—just as we find dwarf specimens of a tree or shrub at high altitudes subject to a frigid zone, as compared with larger examples in warmer localities near the base of a mountain or in the valleys below. Besides this diminution of form, it is observable, also, that the new generations of plants and animals possessed higher organisms, having more perfect organs and functions—as we find exemplified in the common violet compared to the baobab-tree, or the mouse as contrasted with the rhinoceros. But it is evident, from the gradual development of everything on this planet even to its own framework, that these higher organisms would not have existed but for the cruder forms which had gone before. To use a homely illustration: when we look at the small delicately-finished works of a Geneva watch, we do not see in that machine the earliest form of a timekeeper; we must go back to the days when the first clock was invented—a great clumsy machine of wood and brass, standing in relation to the modern watch as an extinct megatherium does to a living mouse. Thus as in art so in nature. The small watch would never have existed but for the big clock; and but for the giants of the tropical era in

Europe, the existing small indigenous animals and plants would not have the perfect structure they represent.

174. *Animals Diminished in Size but Increased in Species during this Epoch.*—As the frigid half of the glacial year changed in the course of time from the diminution of the extended torrid zone, it gradually mingled with the warm moiety, producing an incipient spring on the one hand, and a rudimentary autumn on the other. At first these embryo seasons were probably of not more than a month's duration; then they extended to two months, until at last they reached their equable division of the year into quarters, as at present. In progressing towards this altered condition of the temperature, and the proportions of the solar heat and light that fell upon the earth, there was an increase in the genera and species of the vegetable and animal kingdoms, with an augmentation in the bulk of the arborescent plants and some of the animals. It would appear that the forms sufficient for the alternations of two great seasons of heat and cold were of a simpler character than their successors, when the alternations were more complex, and that nature provided a higher compound organic structure to meet the vicissitudes of the four seasons. On the other hand, the seasons themselves developed functions which altered the nature of these primary organisms, so that new species and genera arose out of the hardiest of their progenitors that survived the rigours of the glacial period. Hence we find fossil remains in the subsequent fresh-water formation, and terrestrial deposits in peat-bogs, of vertebrate animals, mostly such as now live or have become extinct during the historical period. Of these, the most characteristic fossils are the bones of the Irish elk (*Megaceros Hibernicus*), a gigantic member of the deer tribe, which was abundant in the British Isles during prehistoric periods; while a congener (*Cervus alces*) is described by Cæsar and Pausanias as existing on the continent in their time; but both animals are now extinct. These, no doubt, were the prototypes from which the numerous elegant species of the extensive genus of existing deer have sprung; all of which,

be it observed, are smaller in proportion; while a congener —the royal antelope—is the smallest animal of the kind in existence, its feet and legs being as slender as a common pencil; while those of the extinct elk were as large as those of a race-horse.

175. *Destructive Animals Decrease in Species and Harmless Animals Increase.*—From the absence at the present day of any gigantic animals indigenous to Europe, it would appear that the general effect of the epoch of the seasons has been to diminish in size those forms that survived the glacial period in temperate regions. It is also observable that where the species have increased abundantly they are chiefly of a herbivorous or harmless nature; while carnivora or ferocious animals have decreased both in dimensions and species. This is most remarkable among the family of reptiles, especially the frog tribe, these harmless inhabitants of our ponds, no bigger than a wine-glass, being the representatives of an extinct progenitor—the *labyrinthodon*—having a body larger than a hogshead, with capacious jaws fringed with teeth. In like manner the diminutive lizard, found mostly in the southern latitudes of Europe, is the only living representative of the most wonderful and stupendous forms of the animal creation that ever existed—such as the *iguanodon*, *plesiosaurus*, *ichthyosaurus*, *megalosaurus*, besides numerous species of crocodiles and alligators. Thus the advent of the epoch that ushered in the seasons was a period when the destructive powers of the animal creation were succeeded by species of a preservative character, not only harmless in their nature towards man, but providing him with sustenance the most suitable to his omnivorous appetite. The sheep and the ox are peculiarly illustrative of this epoch; and hence, under the hands of man, they have become the most prolific of all animals. It is an open question whether man was in existence during the tropical era in Europe; and if so, how the animal and vegetable food obtainable would have preserved human life, or at all events sufficed to support man as a sentient being, if he escaped the ravages of the carnivorous and

poisonous monsters that were then the "lords of creation." It is evident that the world was scarcely fitted for man's habitation during that period; or if he existed elsewhere than in European latitudes, he was of the very lowest type of humanity, as we now find him in regions where the *quadrumana* dispute the lordship of the forest with the rude aborigines. Moreover, like an era of peace succeeding one of war in human annals, the epoch of the seasons was a period of animal repose, built upon the ruins of colossal organic energy of the most destructive character.

176. *Remarkable Changes in the Vegetable Kingdom.*—In the vegetable kingdom we also observe a distinct change in the structure of plants, with new functions not exercised, as far as we know, by the vegetation of preceding epochs. The most generally striking feature exhibited in this wide domain of observation is that of deciduous vegetation, or the annual fall of the leaf in autumn. Common as this phenomenon appears to the denizens of Europe and North America, yet it is the most remarkable characteristic, of trees especially, that distinguishes the flora of the north temperate zone from that of its southern contemporary, and the great mass of vegetation within the tropical zone. If an intelligent individual, born and brought up in these regions, where the vegetation is perennial or evergreen, and who had never seen a deciduous tree or bush growing, were brought to Europe, and witnessed the fall of the leaves in our forests during the month of October, it would be to him the most wonderful thing in nature. And if he saw our forests stripped bare of their foliage in winter, without being told of their renewal in spring, it would appear to his imagination as if the vitality of nature were dying for ever, and the end of the world at hand.

177. *Trees and Shrubs change their Foliage from Perennial to Annual.*—Now this remarkable feature of European vegetation has not always characterised its arborescent plants. In comparing the fossil flora of our coal-measures with the living flora of Australia, where, as we shall presently see, the

trees and shrubs are all evergreen, it is found that there is a remarkable analogy between them; therefore it follows that the vegetation of Europe, at the period of the carboniferous formation, was not deciduous. During the tropical era the succulent gigantic vegetation was of a similar perennial character to what now exists within the tropics, so there was no regular fall of the leaf during that epoch. And as the glacial period destroyed all the gigantic species of animals, or reduced their organisms to a comparatively diminutive size, so did its rigorous climate in winter extirpate the palms and cycads; while the tree-ferns and stigmarias of giant proportions are now only represented by the humble fern-brake and club-moss. These hardy cryptogamous plants survived the glacial period, though immensely reduced in proportion from their progenitors; but we have no geological data as to the prototypes of the flowering-plants which bedeck the native wilds of Europe. As already observed, the structure of some species, such as the violet, is the most perfect known to botanists, inasmuch as it possesses all the parts of a plant, according to scientific classification, which comparatively few plants possess, while numbers of species, especially tropical plants, are more or less defective in their organs. In the absence of data from fossil flora, we can only refer to existing tropical flowers, which are of proportions gigantic and rude in structure as the animals inhabiting these regions, and which are representative of those seen in fossil zoology. Under circumstances similar to those which, we have seen, tended to reduce the forms of species during the glacial period, we may suppose that the new generations of trees, shrubs, and flowers, which inaugurated the epoch of the seasons, were the remains of the primeval vegetation that escaped extirpation, and continued to "multiply and replenish the earth" during spring, summer, and autumn of each revolving year, until it reached the perfection it now wears.

178. *Changes of the Seasons best known from the Flora of a Country.*—It is here in the garb of flora that the seasons are best known to us in their popular division. We may

mark the meteorological changes of the year as conveying tangible distinctions between one season and another, and the ornithologist may tell us of the migration of birds as indicating the seasons; but it is the wonderful changes that occur in vegetation—the budding, flowering, fruiting, and falling of foliage—that to the denizens of Europe signalise the recurrence of spring, summer, autumn, and winter. The minute chronicler of the seasons is the gardener, who not only registers in his calendar the quarterly appearance or disappearance of every bud, flower, or leaf, but each month has its special horticultural phenomena. Even the bleak winter season is not excluded from his almanac, and he completes the annual report on vegetation by directing the culture of

Spring flowers, and winter bowers;
Autumn fruits, and winter roots.

179. *The Four Seasons Typical of the Vast Periods of Geological Time.*—To descant upon the changes which the indigenous flora of Europe undergoes during the year would be foreign to the purpose of this work, as it is presumed the reader is sufficiently acquainted with its general character to understand any inferences that might be drawn in support of the theory herein advanced. In looking at these changes from an abstract point of view, with reference to their origin, it is not too much to say that, in their annual succession—from a point of wintry lifelessness, through a spring-time of floral birth, maturing in the bloom of summer, to an autumnal decay—we witness changes that are typical of the great geological epochs from whence they have sprung. Thus we may consider the period of the carboniferous formation as the spring epoch of the earth's sempiternal year, which arose out of a primary era of barrenness equivalent to the desolation of winter; while the tropical epoch in Europe was the summer of its leviathan seasons, which has been succeeded by a pliocene epoch as its autumn, and by a glacial period ushering in an epoch that may be considered the winter of these vast divisions of time, compared with which the diurnal and

annual revolutions that mark the seasons are but infinitesimal proportions; and, on the other hand, "each day is as a thousand years" of the vast periods of geological time.

180. *Nature Repeats itself in Living Changes of Extinct Vitality.*—Viewing the recurrence of the seasons in this light, we see the past history of our planet through an annual microcosm that presents the ever-changing nature of its constituent parts in their renovation and decay. It must be observed, however, that in the organic changes of the seasons there is an important difference between them and the changes that occurred during the geological epochs. In what now takes place there are germs in the vegetable and animal kingdoms that continue the powers of fructification, which produce species and varieties similar in organs and functions to those of their progenitors. But in the geological periods of time the first plants and zoophytes arose out of the generative slime apparently spontaneously; and when higher organisms were propagated subsequently, they continued fertile through countless generations until their species became extinct; while they were followed by new forms specifically, and in some instances generically, distinct. Notwithstanding this difference between geological periods and annual seasons, there is a distant analogy which indicates the same vital principle at work in producing those changes. As we find varieties in the flowers produced from the same species, from some casual change in the climate or soil during the year, so may we multiply such changes by myriads of years, and then arrive at a specific distinction in the original plant. Time given, it is quite as easy to understand how one species became extinct and another species was brought into existence, as it is to find a dwarf specimen of a plant, weak and dying, where formerly vigorous and healthy specimens grew; or *vice versâ*, where a sickly decaying shrub one year, from some physical causes, renews its vitality and becomes the strongest tenant of the grove. As it has been said of history in repeating analogous events, so nature repeats itself in all vital changes, however small or great the field of operation.

181. *Migration of Birds a Vestige of the Glacial Period.*—In like manner, whatever changes may have been effected in the functions or instincts of the animal creation through these vast periods of time, there still exist among living creatures vestiges of primary functions which they exercise during the course of years. For instance, the migration of certain species of birds at regular seasons we take to be of this character, as the result of the glacial period. If, as we contend, there were longer periods of extreme cold and heat than at present, the animal creation descended from the tropical era would naturally leave their native latitudes during the rigorous season for more genial climes, and return during the hot season by reason of their instinct to the place of their birth. Where quadrupeds could migrate in this manner they have done so; but, as we have already observed, especially with regard to the British Isles, their progress southward would be cut off by water, and they were forced to remain through the cold season and become acclimatised or perish in the attempt. Not so with birds: possessed of greater powers of locomotion through the atmosphere, unobstructed in their progress by sea or land, rivers, lakes, or mountains, they easily flew away from the cold season that destroyed their insect food to warmer regions where that was abundant at all seasons. Then, on the approach of the hot season, they would return to their native clime at the period of incubation. In all probability, ornithological migration was then upon a much greater scale than we find it at the present day. On the one hand, many species of birds wintered in Europe, as the season was broken up by the autumn, rendering it less severe; and, on the other, species of a more tropical nature were deterred from returning during the early period of the hot season when it was divided by spring—which even now is too cold for the swallow, the harbinger of summer, who makes but a brief stay in northern latitudes, and would be the first to disappear altogether if they became colder, or remain longer if the spring and autumn became warmer.

182. *Probability of the Seasons having passed their Climax.*—Assuming that the diminution of the tropical zone, from a greatly extended belt to its present limit, indicates the commencement of the epoch of the seasons at the close of the glacial period in Europe, it becomes an interesting part of this inquiry concerning their present condition, whether they are before or after the culminating point—an equal division of the year into four parts. This is a very delicate and difficult problem to solve, but we are inclined to conclude they are on the decline towards a period when they will more and more blend into each other so as to be less distinctly defined. The tendency of this diminution is to equalise the temperature throughout the year, having a lower standard during the summer, with an extension of the winter season into spring, though the thermometer may not reach so low a degree as formerly. On this point there is much room for investigation, which might throw new light upon the alterations of the seasons observed within the historic period. The calculations and prognostications of their attendant phenomena—in calendars, almanacs, and other works registering the weather, culture of plants, migration of birds, and the like—are based on the assumption that the four seasons are coeval with the creation of the world. Now, on every hand we may see that there is no phenomenon connected with the transcendent march of time upon the earth that is so evanescent and ever-changing. The very fact of their incessant changeability is a proof of their recent existence in geological time, and having had a beginning, they will have an end; while there is every probability of their having passed the culminating point, and that we are now witnessing their downward march toward a consummation when, as four distinct periods of the year, they will cease to be. It is therefore important that those whose duties are connected with the registration and prognostication of the weather for purposes of utility should base their calculations upon some general principle in accordance with the natural laws that influence the vicissitudes of the seasons, of which there can

be no doubt that the diminution of the obliquity of the ecliptic is the most important. Hitherto it has been treated as a phenomenon too insignificant to have any effect upon the recurrence of each season, or the weather that prevails at stated periods of the year. But when we consider the sensibility of the atmosphere to local influences—some geographical, others meteorological, and even at certain localities agricultural—we cannot reject the theory that this general terrestrial phenomenon exercises its influence in some manner on the weather and the duration of each season. It may not be so apparent as to be reduced to a fixed quantity in one year, but it is just possible that in a long series of years its effects may be traced. When we look at the records of the weather during the latter part of the last century, and compare them with the present, there are many remarkable changes, which meteorologists have not scientifically accounted for, that might be explained satisfactorily upon the basis of this phenomenon, which tends to create milder winters, and generally to distribute the solar heat more equably throughout the four seasons. Even within the past decade of years the mildness of the winters throughout the British Isles, compared with those in the recollection of a living generation, are the common topics of conversation at the recurrence of the festive season that follows the winter solstice. In vain the "Christmas tales" are told of penury and privation from cold, or stories of gladness are published, illustrated profusely by picturesque landscapes bright with snow and ice. Notwithstanding these literary and pictorial forecasts of what the conventional weather should be, the "old-fashioned" winter scarcely puts in an appearance. Art endeavours to perpetuate the former rigorous seasons by the semblance of a hoary monarch crowned with icicles, but nature refuses to obey its quasi-magic power. This was especially the case during the winter of 1868-69 which surpassed its predecessors for unusual mildness, when the reverse was expected by the weather-wise prognostics. In comparing the present with the past it has been remarked, that "A

question of great interest is suggested by the consideration of the weather which now so commonly prevails during our winter months. It seems impossible to doubt that the climate of England has undergone a change of late years. In looking back over the records of the past quarter of a century, one notices a marked prevalence of mild and moist winters. Now and then there has been a bitter spell, but scarcely an instance has been recorded of long-continued frosts, such as used to be experienced of old. If we compare the account given in Gilbert White's 'Natural History of Selborne' of the winter weather experienced less than a hundred years ago, we are yet more struck by the change which has taken place. White's account, for example, of the winter of 1776, describes a state of things such as has not been seen in England for many years. The cold weather began on the 7th of January, and on the 14th the narrow roads were filled with snow to the top of the hedges. From this time the snow continued to increase and stopped the road waggons and coaches, 'which could no longer keep their regular stages, especially on the western roads.' On the 22d, White went to London, and he remarked that the metropolis exhibited a still more singular appearance than the country, being completely bedded in snow. The frost in the evening of the 27th, and afterwards for four following nights, was so intense that the Thames was frozen over both below and above bridge, and crowds ran over the ice. The snow remained twenty-six days without melting on the houses in the city."* To account for the present mildness of our winters, the writer of the foregoing refers to the increased warmth and extension of the Gulf Stream to British waters as the immediate cause. Of this fact there can be no doubt; but as to the origin of the augmented temperature and volume of that great river of the Atlantic Ocean no satisfactory hypothesis has been put forward. Here we may venture to suggest that the contraction of the tropical zone might have reached a point where the intensity of the sun's

* 'Daily News,' December 1868.

rays is more concentrated on the waters at the source of the Gulf Stream during autumn and winter than formerly. At all events, it is just possible that the diminution of the earth's axis of inclination may be an element in producing the observed mildness of our winters; therefore, we recommend the suggestion to the notice of meteorologists.

183. *Difficulty of Prognosticating Changes of Weather.*— Thus it is probable that further inquiry into the cause and effect of diminution in the tropical zones might throw some light upon the mysterious changes of the weather, which sometimes defy the most experienced and learned meteorologists to account for. Yet it is commonly supposed that nothing is easier than to prognosticate what changes may happen in a day, and everybody considers himself in some degree a judge of the weather. When we look forth into the country on a bright summer day, with fleecy clouds passing across the blue sky, refreshing the fields and gardens with genial rain, we are apt to view this delightful phase of the weather as the simplest thing in nature, whereas it is one of the most complex vicissitudes of the seasons. This will be apparent to the most ordinary capacity in the difficulty every person finds —even the most weather-wise—in predicting the occurrence of fine weather. On the other hand, there is a little more certainty in forecasts of bad weather, although the best of these are not always to be relied on. In this country it may be said that unsettled weather is the rule, and fine days the exception, throughout the year. Hence it is a matter of great importance, especially to the seafaring community, to know beforehand the probabilities of violent changes in the weather. Formerly the indications of a coming storm were left to the judgment of the mariners engaged to proceed on their voyage, and of course their observations were limited to what they saw in the weather immediately around them. It having been ascertained that these local indications of change or steadiness were only evanescent, meteorologists suggested that notices from distant localities would be surer guides if they could be forwarded in time. Since the invention of the

electric telegraph we have seen this suggestion put into operation, under the control of a Government department, with considerable success.

184. *The Duke of Buccleuch on the Advantage of Storm-Signals.*—In establishing this meteorological branch of the Board of Trade, no public body has done more service to perfect its arrangements than the British Association for the Advancement of Science. Of their recent exertions to restore its operations, after a short interregnum on the death of Admiral Fitzroy, the Duke of Buccleuch, as chairman of the Association at their Dundee meeting in 1867, spoke as follows:—"Great efforts have been made, and with signal success, by the British Association for the advancement of this science (meteorology), more particularly at Kew Observatory. What I and others have urged on the Government of the day is, the great importance of having renewed and carried on what were called storm-signals at our different ports. I do not mean that we have asked the meteorological department of the Board of Trade to turn themselves into weather-prophets, to give us forecasts of weather; but as they have the power of ascertaining the prevailing winds and storms by telegraphic communication over the whole of the country, and over the continent of Europe — over all the shores of it at least — and to very distant parts, they can inform us where there are great disturbances of the elements prevailing. For instance, there may be a tremendous gale of wind and storm on the south coast of Ireland, and in the entrance to the Channel. Well, notice of that is telegraphed to Glasgow and to Liverpool, and to all the ports upon the west coast, and the commanders of vessels at those ports will hesitate to set sail when they hear of these telegrams regarding heavy storms raging in the very part of the seas which they know they must enter and pass within a few hours. This is of immense value and importance; and I believe much valuable property has been saved, and many valuable lives preserved, by the timely hoisting of the drum signifying bad weather; and those interested can easily, by

application, ascertain where that bad weather is. At the Firth of Forth I have seen the drum hoisted indicating tremendous storms and risks that may be run, and yet not a breath of wind blowing in that particular quarter, though we may have been in the centre of the storm which, perhaps, was raging in the extreme north. Yet, by proper warning, masters may have been hindered from putting out to sea; while some, who have not this simple warning, may have said, 'We may just as well go out to sea, as there is not a breath of wind here;' but then come the newspapers, twenty-four or eight-and-forty hours afterwards, and tell of disastrous gales of wind and shipwrecks upon no very distant portion of the coast."

CHAPTER X.

EPOCH OF THE SEASONS.—*Continued.*

Occasional disparity in the length of the seasons in Europe, § 185.—Great disparity in the seasons of British North America, 186.—This disparity typical of the seasons at the glacial period, 187.—Extremes of hot and cold weather in Northern China, 188.—Vegetation around Shanghai adapted to extremes of temperature, 189.—Plants of a temperate and tropical character growing at Shanghai, 190.—Vegetation of the Himalayan temperate region of altitude, 191.—Seasons there analogous to those of the Alps in Europe, 192.—In the Andes of South America all seasons are blended, 193.—Long summer and short winter seasons of Australia, 194.—A second spring among vegetation after the scorching summer, 195.—No autumnal aspect in the forests of Australia, 196.—Peculiar shedding of bark by the Australian trees in autumn, 197.—The seasons in Australia reversed according to the months, 198.—European plants growing there mark the recurrence of the seasons, 199.—Australian seasons typical of the carboniferous era in Europe, 200.—Seasons in South Africa analogous to those in Australia, 201.—European deciduous trees become evergreen in South Africa, 202.—Mountain waves off the Cape of Good Hope explained, 203.—Mudie's account of the violent spring in South Africa, 204.—Seasons of New Zealand approximate to those of Great Britain, 205.—Spring the prevailing season in New Zealand, 206.—Magnificence and peculiarity of the forests in New Zealand, 207.—Analogy between the New Zealand flora and that of the carboniferous era in Europe, 208.—Return to the consideration of hemispherical disparity of land and water, 209.—Extreme cold of winter at the southern regions of South America, 210.—Concluding remarks on the past, present, and future vicissitudes of the seasons, 211.

185. *Occasional Disparity in the Length of the Seasons in Europe.*—When we speak of the seasons, we naturally associate our ideas with their effects on vegetation and animated nature. On a barren rock or sandy desert, their varied

changes pass without leaving a mark behind; and so, also, on the wide ocean, no vestige remains of their existence, save the glittering iceberg of winter melting under the heat of summer. It is only in latitudes, and on fertile soils, like those of the British Isles, that spring, summer, autumn, and winter present their separate aspects distinctly on the face of nature, dividing the year into four defined portions of time, and leaving behind many vestiges of their effects on the organic world. So well defined is their recurrence, and so important is their influence upon the physical conditions of life, that the popular mind can scarcely suppose a country inhabitable where the seasons do not exist with the same regularity. To those, however, who live in tropical and arctic regions, these quarterly divisions of the year are not apparent; in the former it is one continual summer, and in the latter winter prevails for nine months, while spring, summer, and autumn, are concentrated into the other three. The seasons in their equable succession are confined to the temperate regions, and even there they are restricted in their equal development. In the foregoing section upon the weather and division of the seasons, we have confined our observations to European latitudes generally, and the British Isles in particular. Although we have considered the popular division of the year into four equal parts as the best defined for ordinary purposes, yet it is only conventional, for in reality we find winter running into the spring months, spring into the summer months, and so on with autumn; so that at the best their occurrence as to dates is only approximate. Not only is this the case, but one season may be prolonged in a particular year or shortened in another; of course, when this occurs, the other seasons are curtailed or lengthened accordingly. For example, a long winter may happen, of four or five months' duration—as it did in 1866-67—and be succeeded by a short spring and summer. In this manner a record of the seasons during a number of years would exhibit a great disparity in their duration over or under the allotted three months to each, probably no two years being of equal

proportion in ten or twenty. Where this disparity is uncertain in European latitudes, it approaches a more constant form in other parts of the north hemisphere.

186. *Great Disparity in the Seasons of British North America.*—In the temperate regions of North America, the summer and winter take up about two-thirds of the year, leaving only one-third for spring and autumn; hence the extremes of heat and cold are greater there than in Europe. "In Canada, and that not in the hottest parts of it, in the summer season the thermometer rises to about 102° in the shade, and in winter it sinks to at least 36° below zero or 0 of Fahrenheit's scale. This is 68° below the temperature at which water freezes, and a degree of cold of which the inhabitants of Great Britain have but little conception. One hundred and thirty-eight degrees, or thereabouts, is the average temperature between the two extremes of the Canadian seasons; and when the difference is so great, we can readily understand that a considerable time, as well as great power in the agencies, must be requisite in order to pass from the one of them to the other. The extreme heat of the summer prevents the winter from setting in so early as it does in countries where that extreme is less rigorous. . . . . The labour of the spring in those wild countries is almost entirely confined to the removal of the winter snow; for, by the time the snow and the snow-water are gone, both the temperature of the season and the appearances of the wild plants, have a character deserving the name of summer. This summer comes on apace, and its productiveness both in vegetable and animal action is as remarkable as the stagnation of the energies of life and growth which reigned during the winter." *

187. *This Disparity Typical of the Seasons during the Glacial Period.*—Here, then, we have a region where the disparity in duration of the seasons is considerable—the length of winter and summer being at least double that of spring and autumn. In this respect it approaches to what

* 'Spring,' by Robert Mudie.

we may conclude the seasons were in Europe during the glacial period, when the heavy falls of snow remained on the ground for six months, and in hollows on the mountains all the year round, where the heat of the summer only sufficed to thaw it partially at comparatively low altitudes, so that glaciers covered the rocks in Scotland at places not a hundred feet above the sea-level. Of course America at that period was subject to the same influences, and these latitudes where the above extremes are now experienced, and which correspond with the middle latitudes of Europe, must have undergone the rigours of an arctic winter. Yet from the fossil remains found in its strata, there are abundant data to conclude that, prior to the glacial period, a tropical epoch prevailed there as in Europe, the flora and fauna of which were analogous. As before observed, this suggests the idea that the two continents were then united by what is now the bed of the North Atlantic; and if so, we would have additional data to account for the glacial period by reason of the extremes of heat and cold on continents, which do not prevail on islands.

188. *Extremes of Hot and Cold Weather in Northern China.*—In the middle latitudes of Asia the disparity of the seasons is similar to that of North America, with analogous extremes of heat and cold, and a long range of thermometer throughout the year. This is most observable in North China at the sea-level, or a few hundred feet above it. At Peking (lat. 39° 54′) the thermometer rises to 115° in the shade during an ordinary summer, and sinks to 15° below zero in winter, thus giving a range of 130°; and in some years it has been known to extend to ten degrees more, equal to, if not exceeding, the Canadian range of temperature. Peking has a mean annual temperature of 52° 3′, or more than 9° lower than Naples, which is situated a little farther north. The mean winter temperature of Peking is at least 5° 4′ below freezing-point; while in Western Europe, at Paris (lat. 48° 50′), it is 6° *above it;* again, the winters of Peking are 4° 5′ colder than those of Copenhagen, though the latter is situated 17° of lati-

tude farther north. This rigorous winter, with quite a tropical summer, extends throughout the greater part of North China. Having been resident some years in that country, we can vouch for the excessive heat and cold experienced by the inhabitants, and the rapidity of the growth and decay of its vegetation. Winter is truly a season of barrenness, when the mountains, valleys, and plains are stripped of every green thing, giving an air of desolation to the landscape that has no counterpart in even the poorest lands of Europe. This arises chiefly from the circumstance that in China Proper the fertile lands are laid under cultivation without any hedgerows or grass-lands intervening, while on the hill-country the brushwood and trees have been cut down for fuel or building purposes. Hence the surface of the ground is everywhere denuded of vegetation at the close of the short autumn, presenting a scene of sterility to the traveller that ill accords with the boasted title the Chinese give to their country of "The Great Central Flowery Land." But let him revisit the same region in summer and the whole scene is changed; scarcely a bare spot of ground is visible, from the universal mantle of green that covers the earth everywhere, even up the steep acclivities to the mountain-tops, where native industry has compelled the stubborn soil to yield some vegetable product for the food of man and animals; while the gardens, groves, and even wild thickets are brilliant with the livery of Flora, maintaining to the full the flowery appellation bestowed upon that extraordinary empire by the sons of Han.

189. *Vegetation around Shanghai adapted to Extremes of Temperature.*—During the height of summer, when the greatest heat and humidity prevail, under the influence of the south-west monsoon, the profuse vegetation in the middle latitudes between the cold and hot regions of China partakes considerably of a tropical character, while in winter almost an arctic barrenness prevails. This is especially the case on the low lands of the province of Kiang-soo, formed by the delta of the great Yang-tsze river, of which Shanghai is the central out-

port. In the environs of that city and foreign settlement, we have seen plants growing luxuriantly in the stifling atmosphere of June and July, saturated with humidity, which horticulturists class as hothouse plants, that would perish in the open air if exposed to the comparative mildness of an English winter. Yet these trees and shrubs brave the rigour of a Shanghai winter, when the cold north-east monsoon descends from the Tartarian Alps, and reduces the temperature at night in the depth of the season to zero, or only a few degrees above that point. We have even seen the fan-palm retain some of its leaves, although snow clung to them during winter for six weeks; and where, under ordinary circumstances in Europe, we should have expected the plant to have been killed, it resumed its wonted luxuriance in the following summer, as if the frost and snow had never touched its stem or roots. In like manner the bamboo shoots up to a height of 50 or 60 feet in the hot weather, growing with such rapidity that you can almost see the process going on; and yet this plant retains its vitality during the rigorous winter, although the rapidity of growth is retarded. This power of acclimatisation in plants now existing is evidence that, even during the early part of the glacial period in Europe, the previous tropical vegetation lingered on in its confines and up to its climax, while the extremes of heat and cold prevailed; and it was only when these blended with spring and autumn that the equable temperature extinguished their species.

190. *Plants of a Temperate and Tropical Character growing at Shanghai.*—Another remarkable feature, bearing upon the same point, we observed in the acclimatisation of plants at Shanghai, was the growth of certain shrubs and flowers of an ordinary temperate region, some European, which retained their vitality during both extremes of heat and cold, but only flourished in the short spring, which rarely lasts beyond two months. It was curious to see these humble children of Flora growing by the wayside, or rearing their flowers and branches near a grove of palms, and passing through the process of budding, flowering, and seed-time all within that short season;

then vanishing from the copse at the approach of the tropical heats, not to reappear until the lapse of about ten months. From this fact we can also understand how the existing temperate flora of Europe struggled through the glacial period, leaving a limited number of species from which to propagate at the commencement of the epoch of the seasons. Then, as the spring and autumn expanded their equability of temperature throughout the years, disarming winter of its rigour and summer of its tropical heat, these humble plants grew in size and extent until heaths became shrubs, and shrubs the monarchs of the forest. In its development the vegetation of this new epoch was evidently slower than that of its predecessor, and from that circumstance the trees and shrubs have acquired those exogenous properties of hardness and durability which endogenous tropical trees and shrubs never attain. It will also be observed from these examples of tropical vegetation growing luxuriantly within the north semitemperate regions, that the zones of vegetation marked out by botanists in their theories of the geographical distribution of plants are only approximate, and the exceptions may become the rule in certain localities, as at Shanghai and other places in North China. Thus, as we have seen, as the diminution of the obliquity of the ecliptic has been overlooked by astronomers as an important element in the regulation of the seasons, and by geologists in furnishing a guide to the phenomena of extinct epochs, so have botanists set aside the exceptional data of semitropical floras in endeavouring to retain intact their theory regarding zones of vegetation—exceptions to the rule which, according to the line of argument adopted in this essay, meant to lead to the solution of some problems in the natural history of our planet, as revealed by geology, which are still unexplained.

191. *Vegetation of the Himalayan Temperate Region by Altitude.*—In the foregoing examples of the exceptional character presented by the vegetation of Asia, it is important to note that the localities are near the level of the sea, as there are still more striking phenomena exhibited in temperate

latitudes where the land is elevated many thousand feet above that level. These are seen in their grandest features in India, on the Himalaya Mountains, where the zones of vegetation in altitude comprise all the characteristics of the latitudinal zones, with fewer exceptions to the rule. "Mountains placed between the tropics, the summits of which ascend above the snow-line, represent the vegetable zones of the whole earth, rising one above the other, in the same order as is observed in the direction from the equator to the poles. Proceeding from the level of the ocean in the temperate and frigid zones, we perceive, as we ascend the slopes of mountains, that plants decrease, not only in the size of individuals, but also in their number. At a certain height trees will not grow, still higher shrubs also disappear, and at the limit of snow, mosses and lichens alone are found. The same appearances are remarked under the tropics, with this difference, that here the mass of vegetation is found to be more limited in the plains than in the lower mountain-regions. Such, also, is the case with the greater varieties of species which, in common with these, decrease in an upward direction; and this remark is applicable to the other zones, especially the temperate; since, in the cold zones, the plants of higher regions cannot differ much from those of the plains, because the snow-limits have but little absolute elevation. Besides, the distance of the limits of trees and shrubs from the snow-line is greater in the torrid than in the temperate and frigid zone." *

192. *Seasons there analogous to those in the Alps of Europe.* —In these elevated regions the seasons vary in duration according to the altitude, from almost a continuous winter at the line of perpetual snow, to a long summer in the deep valleys at their base. At the same time, according to Humboldt, "The chain of the Himalaya is placed far beyond the limits of the torrid zone, and scarcely is a solitary palm-tree to be found in the beautiful valleys of Kumaoun and Garhwal." Here the vegetation partakes of the characteristics of European plants. "On the slope of the Himalaya, under the shade of

* Johnston's 'Physical Atlas.'

the deodara and the broad-leaved oak, peculiar to these Indian Alps, the rocks of granite and of mica-schist are covered with vegetable forms almost similar to those which characterise Europe and Northern Asia. The species are not identical, but closely analogous in aspect and physiognomy—as, for instance, the juniper, the Alpine birch, the gentian, the marsh parnassia, and the prickly species of ribes." * The fact that plants of these kinds, well known to flourish only in temperate latitudes, grow on the Himalayas, is proof that the seasons there approximate in duration to those which prevail on the Swiss Alps, having a long winter season, with a brief spring, summer, and autumn.

193. *In the Andes of South America all Seasons are blended.*—In like manner, at certain altitudes in the Andes of South America a temperate zone exists, with a climate of a similar character, but subject to more rapid transitions of temperature, occasioning mountain-storms in winter which surpass in violence any that occur in northern European latitudes. Notwithstanding the astonishing bulk and elevation of the Himalaya, "they cannot, from their geographical position, present the same inexhaustible variety of phenomena by which the latter are characterised. There are some spots in the Andes where the mountains are suddenly cleft into valleys of great depth—where a traveller can stand on the same rock and see the extreme vegetation of India below him, and the sterility of Lapland above. When the rains have fallen for some time, the evaporation produced by them lowers the temperature and brings frost and snow upon the mountains; and the snow-storms there are terrific compared with what they are even in the regions of the extreme north. . . . Countries in which drought and rain are still the chief and only causes of difference of season, and which are subject to such variations of weather, have many returns of spring in the course of the year. The temporary snows speedily melt upon those places where snow is not perennial; and as the fall is of sufficient depth entirely to cover the vegetation, the

* Humboldt's 'Cosmos.'

effect of the brief snow-storm after it is gone is very similar to that of the winter snows of the north when melted by the ardour of the spring. Vegetation is wonderfully refreshed, and sprouts and blooms with the greatest vigour—so that, though the plants of such places are peculiar in their species, they are equally remarkable for their beauty and the vigour of their growth. All seasons of the year may be said to be blended together in these singular countries." *

194. *Long Summer and Short Winter Seasons of Australia.*—While the temperate zone of elevation in South America is characterised by these anomalies in the recurrence of the seasons, there are other regions in the south hemisphere at lower elevations where the seasons are so genial that winter, even according to the mild standard of the south of England, is unknown. This is characteristic of the climate generally in the temperate regions of Australia—places having corresponding latitudes exhibiting remarkable contrasts with those in Eastern Asia. We have seen that at Shanghai, in lat. 31° 15′ N., the thermometer falls nearly to zero in winter, with heavy showers of snow, remaining on the ground for more than a month. Now at Sydney, in lat. 33° 51′ S.—two and a half degrees of colder latitude—the thermometer rarely touches the freezing-point at night in winter, while snow has been only known to fall once or twice on the streets and house-tops, and then to melt rapidly under the morning sun. On the other hand, during the height of summer it is intensely hot, with the thermometer rising to 110°, and sometimes 115°, in the shade. But in consequence of the pecular dryness of the atmosphere, and other influences which we shall refer to in the third part of our subject, the heat is less oppressive to man or animals than in the dog-days of Europe. From being situated in the opposite hemisphere, the hottest months are those of December and January, when they are the coldest with us in Great Britain. But it may be said that both are seasons of barrenness, as far as the growth of temperate vegetation for purposes of food is con-

* 'Spring,' by Robert Mudie.

cerned—the one from extreme cold and humidity, and the other from excessive heat and aridity. While the pastures of England are covered with snow, refusing nourishment to cattle and sheep, those of Australia are parched up, with only scanty tufts of grass and muddy pools of water to sustain the flocks and herds of that great pastoral land, causing the deaths of thousands and tens of thousands of live stock from the want of sufficient food. The seasons there may be classed as a short spring, a very long summer, with the autumn and winter having no clear definition as in Europe. In illustration of this prolonged warm season, it may be mentioned that, in the kitchen-gardens of Sydney, green pease are raised during nine months of the year. At Adelaide, in lat. 34° 55′, similar seasons prevail; but at Melbourne, in lat. 37° 48′, it is cooler during the months of June and July, when the season corresponding to our winter sets in, which increases in rigour at Hobart Town, in lat. 42° 53′, where water occasionally freezes at the sea-level, and the adjacent mountains are covered with snow at their summits for months.

195. *A Second Spring among the Vegetation after the Scorching Heat of Summer.*—Not only is the duration of the seasons in Australia different from what occurs in corresponding latitudes of the north hemisphere, but there is something anomalous in the season that follows the scorching summer, which gives it more the character of spring than autumn. As the hot blasts from the north cease towards the close of February, they are followed by cool gales from the south, generally accompanied by rain, so that the parched soil swells with the moisture, and closes up the gaping fissures on the land. Then the pastures, that by this time are more or less reduced to dust by the hot sun and bush-fires which annually occur in the summer, begin to send forth fresh blades of grass, and though no sward of turf is formed, the plains and open forest-lands are green with verdure. Not only do grasses *spring* forth during this anomalous autumn, but small flowers of orchideous tribes bloom as in spring if

the roots have survived the droughts of summer. On the other hand, deciduous fruit-trees of European species, if they withstand the excessive heat, shed their leaves at this season as in their native country. As already observed, the indigenous trees and shrubs of Australia are evergreen, and their foliage is of that character that it is most luxuriant in the heat of summer, when deciduous foliage is drooping and shrivelled up. At the approach of the autumn season a curious phenomenon takes place, which may be considered equivalent to the fall of the leaf. The bark of the trunk and branches peels off naturally, as clean as if it was stripped by human agency; and where the ground would have been covered with foliage, as in Europe and America at the "fall" of the year, it is strewed with strips of bark, which dangle in the wind and drop from the trees in long ribbons. This curious phenomenon is most observable in the white gum-trees, which acquire a snowy-white new bark when the old one is shed, presenting a remarkable contrast to the fresh green leaves on its branches.

196. *No Autumnal Aspect in the Forests of Australia.*—Thus, while the trees rejoice in the leafy reign of summer from year to year, it is especially characteristic of the seasons in Australia that snow never falls at the sea-level, and the mountains are covered to their summits with evergreen arborescent vegetation. "Australian trees, as well as shrubs, are perennial evergreens. Hence the forests of that vast island are verdant with foliage all the year round. There is no autumnal fall of the leaf, consequently there is scarcely any soil formed in the woods by decayed leaves. As there is no general denudation in winter of the leaves from the branches, so, when spring-time comes round, no universal budding takes place to renew the charms of that season, as in European forests. The well-known American expression, 'fall of the year,' which is derived from its deciduous vegetation, is in this southern region inapplicable. There is a *stereotyped* aspect, if we may so term it, about Australian forest-scenery, so that its general effect upon the mind is that

of monotony. This impression is likewise assisted by the sombre green colour of the foliage, caused by the dark tint of the chlorophyle that constitutes the colouring matter of the leaves. Although the country is open and grassy, and the climate clear and sunny, yet there are no warm green hues in the forest-landscape in spring, nor the rich glowing tints of autumn. A universal sombreness would thus prevail were these effects not considerably modified by the unusual structure of the leaves and bark of the trees belonging to the genus *eucalyptus*, which form, on an average, four-fifths of the forests in the temperate regions of Australia. It is well known that in forests of deciduous trees the leaves project horizontally from the leaf-stalk, showing a distinct upper and under side in the structure of their veins, parenchyma, and epidermis. This position of the leaves gives that umbrageous foliage to European forest-trees which is well marked in the sycamore and elm. In Australia, on the contrary, gum-trees and their congeners have their leaves placed *vertically* upon the leaf-stalk, both sides being of the same structure, like the mistletoe-leaf. Consequently there is abundance of light from above piercing these forests, rendering more cheerful what would otherwise be gloomy in the Australian landscape, and permitting the sun's rays to penetrate through the foliage so as to fall upon the brilliant-coloured flowers and grass which cover the open forest-lands, as it were, with a beautiful carpet. Moreover, the leaves of this class of trees are rarely more than an inch wide and five inches long, being simple, acute, and scimitar-shaped, the branches but thinly covered with foliage, and the trees wide apart; so that, excepting their monotonous character, the open forests of Australia are cheerful to the traveller, salubrious to the settler, and are always well lighted up by the sun and swept by the breeze."

197. *Peculiar Shedding of Bark by the Trees of Australia in Autumn.*—"The autumnal fall of the leaf is likewise in some measure represented by their annual decortication, or natural stripping of the bark from the trunks and branches

of the gum-trees. . . . The appearance of a white gum-tree forest has no counterpart in the northern hemisphere. From the base of the trunk up to the minutest branches the bark of the tree is perfectly white, and the leaves of a leek-green colour. Its general aspect is that which a forest of ash-trees would have if their stems and branches were white-washed. Their trunks, also, are generally naked for about two-thirds of the way up, and the branches above that project at nearly right angles from them, while the smaller branches frequently shoot up vertically. The leaves show the specific character of the foliage alluded to, particularly their leathery structure. On being crushed in the hand an essential oil is expressed from them, which is contained in cavities to preserve them during their perennial existence, and to enable them to withstand the aridity and heat of the climate." *

198. *The Seasons in Australia reversed according to the Months.*—If we compare the phenomena of the seasons in Australia with what occurs here, the exceptions in Europe are the rule there. Being situated in the opposite hemisphere to Britain, its seasons are exactly the reverse of ours. July is the middle of winter, and January of summer. The festivities of Christmas and of the New Year are celebrated there, not, as in the old country, with doors and windows shut, and a cheerful fire to dispel the winter cold, but amid the oppression and the heat of summer, with doors and windows open to invite the refreshing breeze. We no longer hear, in this Australian climate, of the gentle south wind, nor of "rude Boreas, blustering railer." The north is there the region of heat, as the south is of cold. While the extremes of heat and cold occur in the opposite months of the year, the division of the seasons into spring, summer, autumn, and winter, is by no means so clearly defined as in this country. In the island of Tasmania, where the climate approaches more to that of England than the mainland of Australia, when the snow falls on the mountains it remains for weeks and

* S. Mossman, in Rhind's 'Vegetable Kingdom.'

months, according to altitude, and there is a decided winter. The spring and autumn are short and indefinite; while the summer begins in October and lasts from five to six months. In Victoria the winter prevails in a milder degree, except in the vicinity of the Australian Alps, where it is rigorous on the elevated table-lands. Northwards, through New South Wales, it varies according to latitude; and within the temperate zone the spring and autumn become less marked towards the Tropic of Capricorn at Queensland. There the cold season is so mild that it cannot be called winter in the sense known in Europe; and as vegetation is luxuriant all the year round, the seasons may be divided into six months summer, and six months spring and autumn.

199. *European Plants mark the recurrence of the Seasons there.*—"The anomaly of this division of the seasons is, to a certain extent, more apparent than real. Their separation in the northern hemisphere is plain and obvious, in consequence of the deciduous vegetation that prevails—the budding in spring, the blossoming in summer, the fall of the leaf in autumn, and the denudation of foliage in winter. Without these marked changes in the vegetable kingdom, we should be at a loss to divide the seasons. In Australia, the trees and shrubs being evergreen, the foliage apparently never dies; and it is only by the flowering of plants and the appearance of grasses, insects, and small animals, that even the indefinite division of the seasons can be made out. Of course deciduous trees and shrubs from Europe, when transplanted, shed their leaves and shoot forth buds at periods analogous to their seasons, and even these remain longer on the boughs than in their native country, with a shorter season of denudation. As they become acclimatised, this retention of the leaf increases, in some trees more than others, such as the oak; and there is reason to conclude that in time this tree and others may become evergreens, like the South African oak, which was imported many centuries ago from Europe, when it was deciduous, but now it is evergreen. It has been observed that plants from Europe, and other

exotic regions in the north hemisphere, rapidly become acclimatised in Australia; while the contrary is the case among Australian plants brought to Europe. The horticulturist has not yet succeeded in changing the flowering season of many species from the indigenous summer in December and January, to June and July. Hence the Australian heaths are the gems of our winter gardens. Thus it would appear that the Australian flora clings to its own climatic habits in a strange clime with greater tenacity than most others. This may arise from the hard woody fibre of the stems, and the essential oils that pervade the foliage. Though easily destroyed by frost, they will stand the greatest heat without injury, from possessing these properties. Hence the eucalyptus or gum-tree can stand the hot blasts of the sirocco, while the cold damp air of England would destroy that monarch of the Australian forest."* On the other hand, this genus of trees has been successfully reared by the French in Algeria, where the simoom of the desert has no damaging effect on the foliage in summer; and the dry mild winter in that region, accords with the Australian season at a corresponding period of the year.

200. *Australian Seasons typical of Carboniferous Period in Europe.*—Although there is this disparity in the duration of the seasons and their attendant phenomena in Australia, as compared with those of Europe at the present period, there exist data for concluding that, during the carboniferous era, analogous atmospheric and vegetable phenomena prevailed in Europe. In the abundant fossil remains found in the coal-measures of that early formation, the general characters of the extinct European flora and the living Australian flora are remarkably similar. This is not only the case with the arborescent ferns that enter largely into the coal-deposits, but the conifers that chiefly formed the bituminous kinds of coal are identical with the araucarias of Australia, while these are distinct in their tissues from any other class of conifers in the north hemisphere. Botanists have discov-

* 'Our Australian Colonies,' by Samuel Mossman.

ered, in examining thin layers of fossil conifers through the microscope, that they present a double-dotted tissue, while the extensive pine tribe of conifera of Europe and America have them single and in rows; whereas the *Araucaria excelsa* and other Australian pines show exactly the same structure as the fossils. As these araucarias grow only in the warmer latitudes of the temperate regions of Australia, and cannot survive an English winter, we may conclude that the British Isles, during the carboniferous era, possessed a climate and duration of seasons similar to what now prevails at our antipodes.

201. *Seasons of South Africa analogous to those of Australia.*—In the temperate regions of South Africa the duration of the seasons, and their attendant natural phenomena, very much resemble those of Australia, at least in their general characteristics; for in detail they have many specific variations. Both regions are subject to extreme heat and aridity, and long droughts are succeeded by devastating floods. "Southern Africa is the country upon which the south wind tells with the greatest effect. Though not exactly in a tropical latitude, that country gets exceedingly hot and parched during the southern summer. After the heat has dried up the vegetation (and it has begun to do so before the wind shifts to the south), this wind often blows with excessive violence, and its drying and parching qualities are extreme. It begins with what is really the vernal equinox in that country—namely, in September—but the vernal equinox there, as regulated astronomically, is anything but a spring-time upon the earth. The violence of the wind is often terrific; the waves off the Cape roll in congregated ridges, mountain upon mountain, almost as high as the topmasts of a ship. This is the 'south-easter off the Cape,' so well known to navigators. It comes from the sea, not at all deficient in moisture; but it comes from over cool water to sweep along a dry and heated land. The heat is imparted to it, and it speedily dries up all the remaining moisture, withers every herbaceous plant to the ground, and shrivels every leaf. The heat is excessive,

and the clouds of dust during the squalls are most annoying; so that the people of Cape Town are obliged to close their doors and windows, and shut up every opening of their houses, until its fury abates. But, notwithstanding the desolation which it spreads over the fields, and the annoyance which it gives to the inhabitants, it is still the healthy wind of that part of the world, and they term the part of the year during which it blows 'the good monsoon.' It is not a constant wind, but rather springs up in the forenoon, just as the sea-breezes do in some parts of Britain and many other countries, and the intensity of its drought bears away every species of noxious vapour, so that its effect is healthy."*

202. *European Deciduous Trees become Evergreen in South Africa.*—Some of the observations in the above extract require qualification; and in correcting what is otherwise a graphic description of the effects of a Cape "south-easter" we speak from experience, having twice visited the Cape colony, and twice rounded the Cape during the hot season. With reference to the trees, shrubs, and field-plants being shrivelled up by that wind, it applies only to European and other northern vegetation transplanted to Africa; for the indigenous flora flourishes in spite of it, as we have found it does in Australia. For instance, the heaths, those beautiful and numerous species of the genus *Erica* that adorn our conservatories, are like the Australian heaths of the genus *Epacris*, and withstand the hottest blasts of summer; while the native shrubs and trees are evergreen with leathery leaves, analogous to the gum-trees of Australia, which are now to be seen growing luxuriantly at the Cape; so that it is the exotic vegetation which suffers from the heat in South Africa. Some species, however, when acclimatised, such as the African oak, already mentioned, not only survive the excessive heat, but their foliage becomes evergreen, while other plants that are annual in Europe become perennial there after a time. The same phenomenon happens also in Australia, where, in Queensland, the "sea-island" variety of cotton-plant, which is annual in

* 'Spring,' by Robert Mudie.

North America, has become perennial in the course of not more than twenty years' culture. This remarkable property of the climates in the south hemisphere as compared with those in the north, will be discussed more fully in the division treating of the atmosphere, with a view to show that it arises from the difference in the chemical properties of the one aerial hemisphere from the other, irrespective of heat, aridity, or moisture.

203. *Mountain Waves off the Cape of Good Hope explained.* —As to "the waves off the Cape rolling in congregated ridges, mountain upon mountain, almost as high as the topmasts of a ship," by the violence of the winds, of course that must be taken *cum grano salis*, as indeed the author points out in the following note: "Dr Scoresby calculated the waves off the Cape to be occasionally forty feet from the hollow trough to the summit; so that, as Mrs Somerville remarks in her 'Physical Geography,' it is the sublimity of the scene, united to the threatened danger, which naturally leads to an over-estimate of the magnitude of the waves, and has given rise to the proverbial expression, that they appear to rise 'mountains high!'" In this instance, however, the waves off the Cape are higher than any in the open sea, whether the Atlantic, Pacific, or Indian Oceans, but not from the cause assigned. It is in consequence of their moving over the great Agulhas Bank, which extends along the coast a distance of about 560 miles, with a general breadth of 100 miles; but opposite Cape Agulhas it stretches out in a triangular form to upwards of 200 miles. Here the sea is comparatively shallow; and it is well known that when the momentum of a wave touches soundings, the crest rises higher and the trough is lower than where it is not influenced by the land. It is therefore the shallowness of the water, and not the force of the wind specially, which gives rise to the extra "mountain waves" off the Cape of Good Hope. Beyond this bank they do not rise much more than half the height indicated by Dr Scoresby.

204. *Mudie's Account of the Violent Spring in South Africa.* —Returning to Mr Mudie's account of the seasons in South

Africa, we have the following interesting remarks in his book on the 'Spring':—"The spring in this part of the world really takes place about the middle of the winter—that is, it is at its greatest action in June or July, varying a little in different years, as the changes of the seasons do in all countries. The turn of the monsoon, from the season of vegetation to that of drought, begins in September, but it does not acquire its full character till near the middle of the astronomical summer there, which answers that of our winter. By this time the southern waters have acquired the maximum of their summer temperature, which, however, differs so little from that of the opposite season, that the dry and heated land draws from it a constant current of air. This monsoon, or season (for that is the meaning), continues till March, at which time the opposite one begins, but, like the other, mildly at first. It comes with a north-west wind from the Atlantic, which wind is in itself hotter and more charged with vapour when it leaves the ocean than the opposite monsoon is when it leaves the South Sea. It meets the colder air from the south, a contest ensues, and the lightning and thunder are sublime, while the rain falls in torrents, which are often so heavy as to sweep away, not merely the cattle and the crops, but the very soil itself, on the banks of those water-courses which but just before were dry. This is the real spring of Southern Africa, and perhaps it is the most violent spring anywhere to be met with on the surface of the globe. The resistance which it has to overcome is very strong, and the power of this spring—inverted, as far as the astronomical year is concerned—is correspondingly great. It has to contend, not with snow and ice, as in the high latitudes of the northern hemisphere, or with the humidity of winter, as in our own milder latitudes, but with the very extreme of heat and drought. As in every case in nature, however, the very intensity of this heat and drought contains in itself the elements of its own correction, and of a return to the opposite state of things. Whenever the effect of the sun upon the great Antarctic Ocean during the southern summer has, by raising the temperature, caused

the tendency of a current of air from the ocean, the parched surface of Southern Africa is at the very maximum of its power of rarifying the air over it, making the air ascend, and thus demanding a supply along the surface. The state of the Southern Ocean, as just explained, renders it incapable of granting the full amount of this supply; but the general elasticity of the atmosphere which pervades its whole mass, and produces an equilibrium around the whole globe, never fails to send from some quarter or other every supply of air that may be necessary. It is this which brings the Atlantic wind, or north-west monsoon, upon the arid karoos, or dry plains, of Southern Africa; and it is because the southern current still comes there in part—and the two currents are of different temperatures, as the south one comes from the direction of the pole, and the north from the direction of the equator—that such torrents of rain are poured down at this season."

205. *Seasons of New Zealand approximate to those of Britain.*—Besides these continental tracts of land in the south hemisphere, subject to the influences of the temperate zone—namely, in South America, South Africa, and Australia—the islands of New Zealand are of sufficient importance to observe the duration and phenomena of the seasons that occur there. In that region we find a nearer approach to the European divisions than on the southern continental masses; and, from their isolation in the Pacific, they partake something of the climatic changes that occur in the British Isles during the year. Although not exactly in the corresponding latitudes and longitudes of the south hemisphere, yet, for the sake of illustration, they may be considered as our antipodes—bearing in mind always that where the warmest latitudes in England cease at 50° N., the coldest begin in New Zealand at about 48° S. This relative position in latitude adds about ten degrees of heat to all localities in these islands as compared with ours, or, according to meteorological observations, an average temperature there of 59° Fahrenheit to 49° here. Having travelled a good

deal in that interesting colony, we can vouch for it that the climate of New Zealand is better adapted to the English constitution than that of any other of our colonies. The greater preponderance of water over land in the south hemisphere causes a lesser range of temperature in any latitude than in its corresponding parallel of the north hemisphere, where land preponderates over water. The temperature of New Zealand, however, somewhat resembles that of the land between the south of Portugal and the middle of France; or rather, from its insular character, that which Great Britain would enjoy if its centre lay twelve hundred miles to the west of Cape Finisterre. The extremes of heat in summer and of cold in winter are within very narrow limits; for the immense expanse of ocean which surrounds these narrow islands on all sides moderates alike the heat of the tropics and the cold of the antarctic regions. Hot winds and droughts, such as we have seen occur in Australia and South Africa, are wholly unknown in New Zealand; for a never-failing supply of moisture is shed on the mountain-tops and forest-lands by the winds which blow from all quarters of the compass over a vast expanse of ocean. On the other hand, except in the most southern parts, on the high table-lands, or on the summits of the highest mountains, snow is seldom seen after the sun has fairly risen, and never lies upon the ground about the settlements near the level of the sea for a whole day.

206. *Spring the prevailing Season in New Zealand.*—The chief characteristic of the climate of New Zealand as compared with the neighbouring island-continent of Australia is its humidity. Yet there is no distinct rainy season as in the tropics. Although it is rare for a fortnight to elapse without at least refreshing showers, determined rainy weather seldom lasts longer than three days without clear intervals, during which everything, including the atmosphere, becomes quickly dry. This general character, however, applies strictly to the open country, where the vegetation is sparse; for in the forest-lands the trees and underwood are so dense that the

rays of the sun can scarcely penetrate to dry the ground; consequently they are humid more or less all the year round. It rains during all the months of the year, but the greatest quantity falls in June and July and the other cold months, when there is also the greater number of rainy days; while the longest intervals between rain, and the smallest quantity when it does rain, generally occur in December and January and the other warm months. From this showery character of the climate, with intervening periods of sunshine, there is a freshness in the air that rarely occurs in the arid clime of Australia. To a native of the British Isles there is a "scent of home" about it that is pleasing to his mental as well as his physical functions; while a season analogous to spring seems to predominate. It may be said that, from the beginning of August to the middle of December, the "smiles and tears of April" prevail; and if the flora of New Zealand possessed the numerous flowering-plants of Europe or Asia, the groves and plains, the hills and valleys, would revel in the varied hues of a garden. Such, however, is not the case with the indigenous vegetation of these islands, where native flowers are rarely seen, and when found they are small and sober in tint. The smaller plants, both in the forests and on the plains, are chiefly cryptogamous, or what are popularly called "flowerless plants," such as ferns, mosses, and lichens; while the trees mostly belong to the family of conifers. Hence there is little or no indication of spring upon the vegetation from the budding of leaves or flowers. Notwithstanding the favourable climatic influences for the growth of deciduous trees and shrubs, nature has denied these islands the glories of spring, which give such a charm to our own isles at that season. Man, however, in colonising the country, is clearing away the valueless ferns and cultivating useful cereals, while the settlers are rearing every description of flower that may be seen in European gardens, together with hardy fruit-trees and vegetables of all kinds. The division of the seasons in New Zealand may be defined as follows: spring commences in August, summer in December, autumn

in March, and winter in July. Of course, from these islands "extending over 800 miles of latitude, with the varied configuration of lofty mountain-ranges, extensive plains and forest-tracts, there must necessarily exist, irrespective of local influence, great varieties of wind and weather,"* and, consequently, in the duration of the seasons.

207. *Magnificence and Peculiarities of the Forests in New Zealand.*—Here, as in all the southern latitudes, the native trees and shrubs are evergreen—retaining in the cold season the verdant clothing of summer, and what may be called autumnal foliage being cast off by the vigorous renewal of vegetation in spring. The same phenomenon of the timber-trees of Australia shedding their bark annually occurs in a less marked degree among the larger trees of New Zealand, although they are all of different species. In addition to these characteristics, the roots of the trees rarely penetrate the ground on account of the shallow soil, so that they spread out on the surface, forming a rough network of rootlets, which renders travelling through the forests unusually troublesome. When a tree is blown down by the wind the roots stand up like a cake of soil and wood, leaving the rock quite bare. From this it is evident that the trees obtain very little nourishment from the soil, and their luxuriance is derived from the humidity and other properties of the atmosphere. Hence a New Zealand forest is a dense mass of vegetation, with its perennial foliage forming an umbrageous shade, causing a continual twilight of gloomy grandeur. Perhaps there is no forest-scenery in temperate regions that can equal the magnificence they present, vying with the tropical forests of America. What gives them a remarkable character is the underwood being principally composed of tree-ferns from twenty to fifty feet in height, while the stems of the large trees are hung with festoons of beautiful creeping ferns, and clad with mosses and lichens of the most curious forms. The monarch of the New Zealand forests is the Kauri pine, which grows to a hundred and fifty feet in

* 'New Zealand Pilot.'

height, the trunk being bare of branches two-thirds of the way up, forming admirable timber for large masts and spars. Like the greater number of the trees, it belongs to the family of conifers; and this, taken in conjunction with the size and number of the fern-tribe, renders these forests interesting from a geological point of view. We see in them a counterpart of the vegetation that prevailed during the carboniferous period, even more perfect than what may be seen in Australia, which we have already alluded to. In that country there are abundance of flowering-plants; while in the carboniferous formation there are no vestiges of such, and the paucity of these in the New Zealand flora assimilates it with the extinct flora of Europe. We behold, therefore, in the islands of that country a living example of the vegetation of our own isles when the forests were preparing the material which forms our valuable coal-deposits.

208. *Analogy between New Zealand Flora and Carboniferous Era.*—In taking this view of the subject, an interesting question arises regarding the causes which lead to this analogy between the floras of two regions placed at the antipodes of each other, and in point of time so distant in their origin. Geology informs us that the New Zealand islands are all more or less of recent volcanic formation, whereas the igneous rocks of the British Isles are of the most ancient structure; while the fossil flora of the latter is embedded in the oldest aqueous strata, without any equivalent in the former. The inference to be drawn from this is, that atmospheric conditions prevail in the south temperate regions now, similar to those which existed in the northern zone during the carboniferous era. What these conditions are remains to be discussed, and they will form the leading arguments in the division on the air, where it will be shown that there is a remarkable difference between the properties of the atmosphere in the south from those in the north hemisphere. That this difference is the result of other elements than the ordinary properties of heat, aridity, and moisture, may have been observed by the reader, as we have seen that an

evergreen arborescent vegetation is the characteristic of New Zealand, as it is of Australia, South Africa, and South America, where no indigenous deciduous trees or shrubs exist, though every degree of heat, aridity, and moisture may be found.

209. *Return to Hemispherical Disparity of Land and Water.* —By these remarks we are led back to the general question involved in our whole subject as to the origin of the seasons, and disparity between the distribution of land and water in the two hemispheres. "When it is recollected how much more land is heated by solar action than water is heated by the same, it will be perceived that the difference of seasons in the northern hemisphere must be much greater than in the southern; that the spring there must act with far greater energy, and have a correspondingly greater resistance to overcome. . . . The vast extent of sea in the south can never be hotter than the sea is with us in the same latitudes; and over great part of it there can be but little difference between the summer and winter temperature. The air over any surface does not become much hotter than that surface, speaking generally; and therefore there cannot be, even in the height of the southern summer, any very great extent of heated air from the surface of this great expanse of water."*

210. *Extreme Cold of Winter at the Southern Regions of South America.*—Although mildness characterises the temperature of the Cape, Australian, and New Zealand colonies, yet the winter season in Terra-del-Fuego and the extreme southern regions of the South American continent is more rigorous, comparatively, than in corresponding latitudes in the north of Europe. As a rule, there is a difference of some five degrees of cold in these high latitudes, which leads to the inference that there is an ice-bound continent at the south pole. "The cold of the antarctic regions was conjectured by Cook to be due to the existence of a large tract of land between the seventieth degree of south latitude and the pole. The justness of these and other speculations of

* 'Spring,' by Robert Mudie.

that great navigator has since been singularly confirmed by the investigation made by Sir James Ross in 1841. He found Victoria Land, extending from 71° to 79° S. latitude, skirted by a great barrier of ice, the height of the land ranging from 4000 to 14,000 feet, the whole entirely covered with snow, except a narrow ring of black earth surrounding the huge crater of Mount Erebus, rising 12,400 feet above the level of the sea. The position of a mountainous territory of such altitude so near the pole, and so obvious a source of intense cold, fully explains why Graham's and Euderby's land, discovered by Captain Biscoe in 1831-32 (between latitude 64° 68° S.), presented a most wintry aspect, covered even in the summer with ice and snow, and nearly destitute of animal life. In corresponding latitudes of the northern hemisphere we not only meet with herds of wild herbivorous animals, but with land which man himself inhabits, and where he has even built ports and inland villages."* This evidence of the existence of a south polar continent we alluded to in describing the configuration of the solid parts of the earth, as an equivalent in elevation to the depression of the north polar sea.

211. *Concluding Remarks on the Vicissitudes of the Seasons.* —Thus it will be seen that not only are the seasons of varied duration, according to the local influences of sea and land, in all the temperate regions of the earth, but that the disparity in the surface-distribution of ocean and continents gives a general character to their recurrence in the south, which differs considerably from the phenomena in the north temperate zone. Taking the seasons occurring on the British Isles as the standard of equal duration, we find in the far east the winter and summer prolonged, with extremes of heat and cold; while in the distant south temperate regions the divisions of winter, spring, and autumn are so blended together that their distinguishing features are not recognisable. Exceptions to the rule may be found in every region, and in no two regions do they occur alike. As each season in its

* Lyell's 'Principles of Geology.'

relation to the other is the result of incessant change, so each group of seasons differs from another according to the physical features of the country, and these in the course of geological time have altered in their duration and phenomena. From whatever point of view we consider their relations in the economy of nature, the seasons have originated in vicissitude, they flourish in vicissitude, and in vicissitude they may disappear. Instead of being examples of the eternal laws of heat, light, and gravitation that pervade the universe, they are exceptions to the rule, presenting only a transitory epoch in the history of the earth.

PART II.

THE SEA

CHAPTER XI.

THE PRIMEVAL SEA.

Mean density and average depth of the sea ascertained, § 212.—Hydrostatic figure of the earth in rotation orange-shaped, 213.—Depression at the poles compared with that in Jupiter, 214.—M. Plateau's experiment illustrating the principle of planetary centrifugal force, 215.—Rotation and bulk of the earth probably lessened, 216.—Extraordinary computation of the earth's rotation, 217.—Serenity and monotony reigned over the primeval sea, 218.—Maury's description of the basin of the Atlantic, 219.—How continents might be levelled into the depths of the sea, 220. - Probable average depth of the primeval sea, 221.—Has the sea diminished in volume since that period? 222.—Geology shows that land is formed by deposits from the sea, 223—The moon an example of a world without a sea, 224.—Recent observations of the lunar surface confirmatory of this, 225.—Lockyer's theory of the lunar seas being engulfed in the cavernous interior, 226.—The moon a prophetic picture of the ultimate fate of the earth, 227.—The existence of the sea depends upon great internal heat, 228.—The sea contains atoms of all soluble minerals and metals, 229.—Analysis of chemical ingredients found in sea-water, 230.—Primary bed of the sea formed by microscopic silicious shells, 231.—Captain Maury's remarks on the abundance of calcareous shells and absence of sand at the sea-bottom, 232, 233.—Professor Bailey's remarks on the animalcules of these shells living in the upper waters and sinking after death, 234, 235.—All the limestone series of rocks formed of fossil zoophyte remains, 236.—The bed of the primeval sea formed of extinct species of shells, 237.—Dr Carpenter's estimate of the enormous increase of animalcules, 238.—Silica a large ingredient in the primeval sea now exhausted, 239.—Crystalline rocks may have been originally formed of silicious shells, 240.—Speculative views on latent vitality and spontaneous generation, 241.—Sequence of organic life traced back into the inorganic world, 242.—Saline solutions discovered in granite, and silver in the sea, 243.—Silicious rocks originally formed the bed of the primeval sea, 244.

212. *Mean Density and Average Depth of the Sea ascertained.*—At the commencement of the foregoing division,

when treating of the solid parts of the earth as affecting its hemispherical equilibrium, the fluid parts which lie in the hollows of its surface were only casually referred to. It was inferred that the sea, notwithstanding its extent and depth, is small in ponderosity as compared with the bulk and density of the land. According to Lyell, "the mean density of the earth has been computed by Laplace to be about 5½, or more than five times that of water. Now the specific gravity of many of our rocks is from 2½ to 3, and the greater part of the metals range between that density and 21. Hence some have imagined that the terrestrial nucleus may be metallic—that it may correspond, for example, with the specific gravity of iron, which is about 7. But here a curious question arises in regard to the form which materials, whether fluid or solid, might assume, if subjected to the enormous pressure which they must obtain at the earth's centre. Water, if it continued to decrease in volume according to the rate of compressibility deduced from experiment, would have its density doubled at the depth of ninety-three miles." Whether the sea attained a greater depth before the land rose above its surface than at present, there are no data for computing; therefore we must confine our calculations to the knowledge we possess of the ocean as it now appears. Its deepest parts are ascertained to be not more than seven miles, giving a probable average for the entire superficies of the earth of perhaps four miles. When we compare this with the earth's mean diameter of 7912 miles, and the average gravity of five and a half times that of water, we may conclude that if the movements of the sea exercised any direct influence in displacing the planes of our planet's diurnal and annual rotation, according to our theory, it must have been more of a negative than a positive character, by reason of its fluidity reacting upon the forces that upheaved the land, according to the law of oscillation.

213. *Hydrostatic Figure of the Earth in Rotation Orange-shaped.*—Hitherto we have considered the configuration of the earth, and the land phenomena leading to the origin of

the seasons, from a strictly geological point of view, as exemplified in the solid structure of its external crust. This we have compared, for the sake of illustration, to a common top, with an apex at the south pole and depression at the north pole of revolution. We now come to consider our planet as a hydrostatic sphere, influenced by the law of centrifugal force, which increases its fluid circumference of rotation, and depresses both axes of diurnal revolution. Hence the world has been familiarly compared to an orange; but this should be qualified by adding that the orange ought to be spinning rapidly on a pivot through its centre and across its least diameter. In the former instance, we have viewed the solid fabric of the earth in repose, as it would appear if axial rotation ceased, and the waters had disappeared from its surface; and, in the latter case, it comes before us in all its activity of daily movement, where a true spherical form of revolution is not only reached, but maintained in excess, by the greater circumference of the equatorial latitudes over the polar, when measured at the level of the sea. This is the astronomical figure of our planet, which Newton designated an oblate spheroid before it was mathematically demonstrated; and the hydrostatic theory of the earth goes to prove that the internal solid parts must have been deposited in an elliptical form. "However irregular the surface of the earth may be in its details, its general form agrees so nearly with the figure of hydrostatic equilibrium, that the agreement cannot be regarded as fortuitous or accidental. The regular increase of gravity from the equator to the poles also proves that it is symmetrically constituted, or that the materials in its interior are disposed about the centre of gravity in regular elliptical strata, and arranged according to the order of density. The earth must therefore have taken its present form while its particles were at liberty to arrange themselves in obedience to the forces arising from their mutual attractions, and from their rotation; in other words, it must have existed at some period of time in a state of fluidity."*

* Art. "Figure of the Earth," 'Encyclopædia Britannica.'

214. *Depression at the Poles compared with that in Jupiter.*—Although the sea is now, and has been for countless ages, inferior to the land as a component part of the terraqueous globe, yet it is the opinion of many eminent astronomers and geologists that in earlier epochs, when our planet's density was less and its bulk greater, water formed a larger proportion of the terrestrial matter than it does now. It is even held by some as a cosmical theory that our planet, in its primary elementary state, passed through an aqueous condition, from which the solid nucleus was precipitated. Into these hypotheses we shall not enter at present. Our investigations into the phenomena of the sea, bearing upon the disturbance of the equilibrium of the land, begin at that epoch when the depths and shallows were being formed by upheavals and sinkings of the solid matter which, by refrigeration, now forms what geologists term the "crust of the earth." At this period the sedimentary rocks, we assume, were in a plastic state, so as to be affected by centrifugal force; but, from their greater density and tenacity, the depression at the poles would be less in proportion at the bed of the sea than on its surface. Whether the oblateness of the terrestrial spheroid was greater then than now, is a question impossible to determine, as that would depend upon the velocity of the diurnal rotation, according to the experimental illustration we shall presently quote. That it is not unphilosophical to moot the inquiry, is obvious from the observations of astronomers regarding the rotation and form of the planet Jupiter. "The radius of Jupiter being nearly 11 times (10.86) that of our earth, his rotation 2.4 times more rapid, it follows that the space passed over by a point on his equator is 26 times greater than that passed over by a point on the terrestrial equator at the same time. Hence the centrifugal force is 26 times greater; and if the spheroidal form of the earth is occasioned by the diurnal motion, we may expect to find the same effects, on a much larger scale, exhibited in the form of Jupiter. And this is in fact observed to be the case; for, according to Struve, the compres-

sion of Jupiter is about $\frac{1}{14}$th of his radius, the diameter of his equator being to that of his poles as 14 to 13 nearly; while that of the earth is only $\frac{1}{306}$th *—that is to say, the equatorial is to the polar diameter in the ratio of 306 to 305, or a compression of 27 miles.

215. *M. Plateau's Experiment illustrating the Principle.* —"Some very curious physical experiments, imagined by M. Plateau, account in the most satisfactory way for the phenomena which we have just described; they appear to us well adapted to dissipate the obscurity which a description of such an abstract conception would naturally leave in the minds of some of our readers. These experiments consist essentially in freeing a fluid mass from the action of gravity in such a manner that all its parts may be merely acted upon by their mutual attraction, and in imparting afterwards to this mass a movement of rotation more and more rapid. To do this, M. Plateau places a quantity of oil in a glass vessel filled with a mixture of water and alcohol, the lower strata of which are more dense than oil, whilst the upper strata are lighter. The mass of oil descends in the mixture as far as the stratum of the same density, where it remains, taking the form of a sphere. In this state the mass of oil is freed from the action of gravity, and the form which it takes is due simply to the mutual attraction of its molecules. Next, by the help of a metallic disc, introduced with care into the sphere of oil, and a stem which passes through its centre and communicates with a handle, M. Plateau imparts to the system a progressive movement of rotation. When this movement is slow, the sphere is transformed into a spheroid, swelled at the equator, flattened at the poles, under the action of the centrifugal force, which develops the movement. The phenomenon accounts, then, perfectly, for the form of the planets. If the movement becomes more rapid, the flattening becomes more considerable; the spheroid becomes indented at its poles, spreading out more and more in the horizontal direction, until the oil, entirely leaving the disc,

* Art. "Astronomy," 'Encyclopædia Britannica.'

is formed into a circular ring. At this moment the phenomenon at once explains both the zones detached at the origin of the solar mass and the rings of Saturn. Lastly, if the rotatory movement, rendered more rapid, is continued with a disc of a diameter sufficiently large, the centrifugal force, in driving the particles of the surrounding medium towards the ring, soon separates it into isolated masses, which form themselves into individual spheres, each of which preserves for a certain time a movement of rotation of its own in the same direction as the ring. This last phase of the phenomenon offers a striking analogy with that of the formation of the centres of condensation which, on Laplace's hypothesis, are the origin of the planets of our system."*

216. *Rotation and Bulk of the Earth probably lessened.*—Without considering whether the earth at one time had proportionate dimensions to the enormous bulk of Jupiter, when its mean density approximated to the lighter matter of that planet, or its diurnal revolution was ever proportionately as rapid, we have here data to speculate upon the probability that, at some period anterior to the upheaval of the land, it revolved on its axis with greater rapidity than at present, and the oblateness of its spheroidal form was probably greater. Moreover, the depth of the circumambient sea would be less at the poles than the equator. Assuming this to have been the case, we draw the inference that the upheaval of the continental masses, dividing the sea into numerous branches, probably affected the diurnal rotation of the earth, so that day and night may have lengthened. On this point astronomers conclude that there has been no alteration in the *equation of time* throughout the year, although astronomical or solar days are not equal. "Two causes in particular conspire to produce their inequality—namely, the unequal velocity of the sun in his orbit, and the obliquity of the ecliptic." Here it is sufficient merely to note that even the length of each day is subject to change throughout the year, and that it is possible the revolution of the earth on its axis

* 'The Heavens,' by A. Guillemin.

was performed in a shorter space of time than the twenty-four hours into which man has divided it.

217. *Computation of the Earth's Rate of Rotation.*—A writer in one of our popular periodicals furnishes a computation as to the length of time that must have elapsed to increase the day by one second, and the period when diurnal rotation may be expected to cease, as follows:—"There are 86,400 seconds in a day of the current anno domini. If it requires 100,000 years for the day (in consequence of the earth's more sluggish rotation) to increase by the 86,400th part of its length, it will take 8,640,000,000 of years to cause that rotation to cease altogether, supposing the slackening of its speed to continue under the same conditions. Will it ever cease? Will the earth ever come to a stand-still, as far as her rotation is concerned? No, she will not. Her rate of spinning is gradually slackened, because she spins faster than the moon, who thereby raises the water into a heap, converting it into a brake or drag. But when once the earth spins no faster than the moon, she will always have the same hemisphere turned towards her satellite; the liquid protuberance will be no longer carried forwards, and the moon will have no further hold whereby to check the earth's rotation. The period of the earth's rotation would then coincide with that of the moon's revolution round the earth. In short, the earth at last would constantly turn the same face to the moon, exactly as the moon turns the same to us. It is only natural to suppose that the very same cause has produced the singularity which we observe in the motions of the moon. If she always turns the same face to the earth, the cause ought to be analogous to that now submitted to your consideration. But things may not even go so far as that. As time slips away, the earth's temperature is expected gradually to drop. The waters of the ocean may be converted into ice: with no more water there will be no more tides; the cause of the slackening of the rotatory movement will disappear, and the earth will thenceforth continue to turn with a constant velocity. The exact amount of slackening is not yet known;

it is ascertained approximately only by the indications afforded by ancient eclipses. Its accurate determination must be a work of time." *

218. *Serenity and Calmness reigned over the Primeval Sea.* —Confining our investigations to the geological part of the subject, the first question that presents itself is the physical condition of the primeval sea in relation to the diurnal and annual revolutions of our planet. That these were of the simplest character is abundantly evident from the data furnished by the earliest stratified rocks. Compared with the present intricate "Physical Geography of the Sea," as the study is designated by Humboldt and Maury, its currents, tides, and other phenomena must have been of the most rudimentary nature. Assuming that the equatorial plane was parallel with the earth's orbit, or only slightly displaced, the distribution of solar heat over the sea would be unbroken throughout the year, with a superincumbent atmosphere encircling the waters, having isothermal lines corresponding with the parallels of latitude. The sea being unbroken by the submerged land would have a uniformity of current, caused by its diurnal rotation, only disturbed by lunar attraction and other perturbations of the heavenly bodies, which had then but little influence on its general condition. In this pristine era, a universal sameness and monotony prevailed over the "boundless deep," save when its surface was agitated by the winds, and even these would be of a monotonous character, having no land to influence their direction or variation. Day and night were equal from pole to pole throughout the year, and belts of clouds hung over the sea, in certain latitudes encompassing the watery globe. The currents of the ocean were more or less uniform with the currents of the air, and these followed the laws that regulated the diurnal revolution of the earth. Everywhere a universal serenity reigned over the primeval sea. If a sentient being could have visited our planet at this epoch, and sailed over its endless watery expanse, his mental energies would have

* 'All the Year Round.'

collapsed with the eternal sameness of day and night, sea and sky, heat and light.

219. *Maury's Description of the Basin of the Atlantic.*—In like manner the bed of the primeval sea was probably of a uniform depth from its surface—always excepting the difference between the polar compressions of the plastic land and the water. If it were possible to ascertain the mean depth of the present ocean, it would furnish data for an approximate computation of the average depth of the body of water which covered the earth at this period before any of the land was upheaved. Maury, in his work on the 'Physical Geography of the Sea,' has constructed a chart of the basin of the North Atlantic Ocean, with numerous soundings, showing a probable average of 3000 fathoms, or upwards of three miles. Of its general character he remarks as follows: —"In its entire length the basin of this sea is a long trough, separating the Old World from the New, and extending probably from pole to pole. This ocean-furrow was scored into the solid crust of our planet by the Almighty hand, that there the waters which 'He called seas' might be gathered together, so as to 'let the dry land appear,' and fit the earth for the habitation of man. From the top of Chimborazo to the bottom of the Atlantic, at the deepest place yet reached by the plummet in the North Atlantic, the distance, in a vertical line, is nine miles. Could the waters of the Atlantic be drawn off so as to expose to view this great sea-gash which separates continents, and extends from the arctic to the antarctic, it would present a scene the most rugged, grand, and imposing. The very ribs of the solid earth, with the foundations of the sea, would be brought to light, and we should have presented to us at one view, in the empty cradle of the ocean, 'a thousand fearful wrecks,' with that dreadful array of dead men's skulls, great anchors, heaps of pearl and inestimable stones, which, in the dreamer's eye, lie scattered on the bottom of the sea, making it hideous with sights of ugly death."

220. *How Continents might be swallowed up in the Deep*

Sea.—On the other hand, could we imagine the mountain-chain of the Alleghanies hurled into the profound depths of the North Atlantic, and the table-lands of Mexico shovelled into the Gulf of Florida, until its bed became comparatively level, it would present the aspect of a more uniform sea—undisturbed by wayward currents, or that wondrous ocean-river, the Gulf Stream—similar to what it was at the period under consideration. Still, its average depth would be greater than the primeval sea, as the continental masses themselves would have to be cleared away, not only level with the surface-waters, but down, down, two or three thousand fathoms, until the ocean-bed was raised to that average, or the apparent mean depth delineated in Maury's chart. Then all traces of land above the sea-level would be gone, and the submarine mountains and valleys, plains and precipices, would no longer "present a scene the most rugged, grand, and imposing;" while "the empty cradle of the ocean," with that dreadful array of men's skulls, great anchors, and "a thousand wrecks," would be buried under the tremendous superincumbent debris.

221. *Probable Average Depth of the Primeval Sea.*—Assuming, for the sake of illustration, that the average depth of the primeval sea was 20,000 feet, or about four miles, we may form some idea of the immense body of water that enveloped the earth before the upheaval of the land. Yet this was a light stratum only, covering the vast bulk of the globe, when compared with its diameter of 7000 miles, and mean density of 5½ to 1 of water. At the same time, the pressure of such a column of fluid upon the plastic crust of the earth must have exercised a counteracting influence in suppressing the internal volcanic forces that upheaved the continental masses; and we may thereby estimate the greater power of the primary agencies that had to contend with that pressure, compared with subsequent and modern volcanic forces battling only against shallow seas or atmospheric pressure. There must have been a tremendous struggle between the igneous internal force and its opposing aqueous external pres-

sure to obtain the mastery. We have fully considered in the first part of this work how the former succeeded, not only in shaking the framework of the earth to its centre, but impelling its axis from its normal position. We have also advanced that there was a corresponding subsidence of the earth's crust as the continental masses were upheaved. At these periods it is not unscientific to conclude that the rush of waters displaced by the upheaval of the land into the depressions of the sea-bed would give a negative impetus to the one grand work of the displacement of the equatorial plane from the orbit of the earth. And as the greatest upheaval of the land was in the north hemisphere, so the rush of waters to maintain the ocean-level would be towards the south hemisphere, throwing their weight with some force into the opposite scale, and thus aiding in driving the earth off its balance.

222. *Has the Sea diminished in Quantity since that Period?*—It becomes here a subject of interesting inquiry whether the sea, at the period under consideration, altered its level, in relation to the centre of gravity, by a diminution of its fluid or increase of its solid parts. As far as human calculations can penetrate into the past condition of the sea from geological data, and the evidences furnished during the historic era, this question has not been satisfactorily determined. According to the general principle inferred from the foregoing section, that there was an equivalent to the upheaval of land by its subsidence, the mean level of the sea would not be affected permanently, however much it might have been transiently in some places. We can understand how the Atlantic, when first shaped by the continental masses that determine its shores, was considerably higher in its level than at present, from the waters displaced by the land partly rushing into its valley. But when the surplus waters flowed towards the south to fill up a lower level caused by subsidence, they would sweep along with immense velocity, like a flooded river rising between its banks, until the current reached the unconfined Southern Ocean and the

Pacific, where they would spread out in comparative quiescence, as the rushing stream forms a lake on the plain. Then the Atlantic would fall and the Pacific rise to the universal level. It is not long since hydrographers settled the question whether the levels of these two oceans were the same—some observers having stated that there was a difference of several feet; so that, in the event of the proposed canal being cut through the Isthmus of Panama, there would be a constant current from the Atlantic to the Pacific. The supposed difference of level, however, was ascertained to be the difference of tides only—the variation at the times of observation, with the rise and fall on each side of the isthmus, being variously affected by local causes.

223. *Geology shows that Land is formed by Deposits from the Sea.*—When meteorologists and hydrologists inform us that there has been no change in the volume of the atmosphere and the sea since the creation, we must receive their statements with the same qualifications that we have done with regard to those bearing upon the immutability of the seasons. There is abundant geological evidence to prove that a great portion of the earth's crust was deposited by the sea, as it is conjectured that the volume of the sea may have been augmented by the watery deposits of the primeval atmosphere. We do not allude here to the agency of water in the formation of sandstone and cognate rocks, or humidity caused by evaporation forming rain-clouds, and the like, which are only modifications of these elements. Irrespective of these modifying agencies, there are others at work, and have been at work from primeval time on this planet, which have produced many of the physical phenomena that now exist. As a rule, aqueous matter from chemical affinity tends to become solid, as aeriform matter by the same law has a tendency to become fluid. Thus it may be said that all the elements on the surface of the earth will ultimately resolve themselves into a solid form; so that, in the course of immeasurable periods of time, the sea and the air will disappear by solidification into the framework of our planet. Then

would the whole of the animal and vegetable creations, which make this world so beautiful, become utterly extinct, and its whole circumference, from pole to pole, present the aspect of a howling wilderness, like her own satellite the moon, which astronomers represent upon sound data to be an oceanless sphere, without a life-breathing atmosphere.

224. *The Moon an Example of a World without a Sea.* —"The dark spots on the moon's surface were formerly supposed to be water, but as elevations and cavities are distinctly perceptible in them, that hypothesis is evidently erroneous. Besides, the extreme tenuity of her atmosphere is inconsistent with the existence of water at her surface. It is only by the weight of the terrestrial atmosphere that the liquids at the surface of the earth are prevented from being dissipated in vapours. If the present atmosphere were removed, every liquid would continue to be dissipated in this manner till a new atmosphere was formed, to which each would contribute in proportion to its elastic force; and the evaporation would only cease when the tension of the vapour of each liquid was equal to its elastic force in a vacuum at the same temperature. But if the vapours were removed as they arose by any absorbing cause, the evaporation would continue until the liquids entirely disappeared. Now we may suppose this to be the case with respect to the moon, and that at one time she may have had an atmosphere which the attractive force of the earth, aided by some accidental circumstance, may have swept away and united with our own. Under these circumstances, it is evident that no animal similarly constituted to those which inhabit the earth could respire at the surface of the moon. Everything there appears solid, desolate, and unfit for the production of organised substances; and the excessive cold which certainly prevails must be sufficient to destroy every source of animal or vegetable life. May it not then be supposed that the moon is a planet which has not yet reached a state of maturity—a maturity to be prepared by successive volcanic eruptions; or that, having fulfilled its destiny, it is now in a

state of decay?"* In replying to that question we would incline to the latter suggestion, as more consonant with the theory set forth in this work, and according with the views of the most profound geologists, that all the solid matter of this earth has been consolidated from a liquid and aeriform condition. With regard to the hypothesis in the foregoing extract, that if the earth had no atmosphere the waters would evaporate until they disappeared—this may be true in the abstract; but the writer forgot to mention what would become of these atoms of matter, which, of course, could not entirely leave the earth, by reason of the attraction of gravitation, consequently they would resolve themselves into solid matter. Applying the same principle to the waterless, if not airless, condition of the moon, it is more consistent with the physical laws of nature that her possible primary life-giving atmosphere became absorbed within her own solid framework, than that "the attractive force of the earth, aided by some accidental circumstance, may have swept it away and united it with our own;" and that her seas have collapsed within her hollow sphere as the crust cooled.

225. *Recent Observations of the Lunar Surface confirmatory.*—From numerous recent observations of the moon's surface by Lord Rosse's powerful telescope of six feet aperture and sixty feet focal length, as well as other large instruments in British and foreign observatories, it has been determined by astronomers that the moon is devoid of air, and that the absence of air implies absence of water. "If there existed lakes, seas, or even rivers, the liquids forming these reservoirs or currents would be reduced to vapour by the fact that they would not be maintained as such by atmospheric pressure. But the solar heat acting still more energetically would develop a gaseous envelope. . . . The large dark spots which the first observers took for seas, are now known to be vast plains, lower in level than the valleys of the mountain-regions. One thing which doubtless, in the first instance, increased the illusion was, that many of these

* Art. "Astronomy," 'Encyclopædia Britannica.'

spots appear of a light greyish-green colour; others are greenish-grey, reddish, or, again, of a deep grey, like steel. The absence of waters, and—as a natural consequence—of rains, is so much the more probable, as it well explains the present appearance of the surface of the moon, or, in other words, the geology of its superficial strata."*

226. *Lockyer's Theory of the Lunar Seas being engulfed in the Moon's Interior.*—"Instead of seas they are most probably old sea-bottoms. Such, then, are the results of the telescopic observations of our satellite turned towards us. Do we know anything about the like conditions of the side turned away from us? or, again, can we dive into the past history of the moon? The illustrious Hansen has held that it is quite possible that the lunarians on the side away from us may possess both water and an atmosphere, and that the side turned towards us may be regarded as one vast mountain. Adams and Le Verrier, however, have shown that such a hypothesis is not very securely based. . . . With regard to the probability of former aqueous agency on the surface of the moon, difficulties of an apparently very formidable character present themselves. There is not only now no evidence whatever of the presence of water in any of its three forms on the lunar surface, but, on the contrary, all selenographic observations tend to prove its absence. Nevertheless the idea of former aqueous agency in the moon has received almost universal acceptation. It was entertained by Gruithuisen and others. But if water at one time existed on the surface of the moon, whither has it disappeared? If we assume, in accordance with the nebular hypothesis, that the portions of matter composing respectively the earth and the moon once possessed an equally elevated temperature, it almost necessarily follows that the moon, owing to the comparative smallness of its mass, would cool more rapidly than the earth; for whilst the volume of the moon is only about $\frac{1}{49}$th, its surface is nearly $\frac{1}{13}$th, that of the earth. This cooling of the mass of the moon must, in accordance with all

* 'The Heavens,' by Amadée Guillemin.

analogy, have been attended with contraction, which can scarcely be conceived as occurring without the development of a cavernous structure in the interior. Much of this cavernous structure would doubtless communicate by means of fissures with the surface; and thus there would be provided an internal receptacle for the ocean, from the depths of which even the burning sun of the long lunar day would be totally unable to dislodge more than traces of its vapour. Assuming the solid mass of the moon to contract on cooling at the same rate as granite, its refrigeration, through only 180° Fahrenheit, would create cellular space equal to nearly 14½ millions of cubic miles, which would be more than sufficient to engulf the whole of the lunar oceans, supposing them to bear the same proportion to the mass of the moon as our own oceans bear to that of the earth."*

227. *The Moon a Prophetic Picture of the Probable Fate of the Earth.*—According to this hypothesis of the disappearance of former lunar oceans, and the surface of the moon presenting only the solid framework of its sphere, we have before us, within scope of our far-searching telescopes, an example in the solar system of what the earth would be like divested of its seas, as we have endeavoured to picture in the first section of our work. The absence of water from the ocean-beds accounts also for the great heights of the mountains as compared with those on the earth, inasmuch as these are estimated from the depths of former sea-valleys of the satellite; whereas in the parent planet they are calculated from the level of the sea. Taking these modes of computation into consideration, there is not so great a disparity between the elevation of the terrestrial and lunar mountain-chains and crateriform mountains as we have hitherto been led to suppose. The highest of these are in the vicinity of the southern pole: there Dörfel is found, the summit of which attains 26,691 feet in altidude; the mountains Casatus and Curtius are 21,234 and 22,227 feet high. In all probability, however, when the moon had its extinct sea,

* J. Norman Lockyer, F.R.A.S., in 'The Heavens,' by Guillemin.

these would not have been half their elevation above its level; and if the earth was oceanless, like her satellite, the Himalayas and the Andes would attain an altitude of from 50,000 to 60,000 feet above the deepest valleys of the Pacific and Indian Oceans, while Gaurisankar would be 63,360 feet —a vertical height of twelve miles or so. "Now, if such be the present condition of the moon, we can scarcely avoid the conclusion that a liquid ocean can only exist upon the surface of a planet so long as the latter retains a high internal temperature. The moon, then, becomes to us a prophetic picture of the ultimate fate which awaits our earth; when deprived of an external ocean, and of all but an annual rotation upon its axis, it will revolve round the sun an arid and lifeless wilderness, one hemisphere being exposed to the perpetual glare of the solar rays, the other shrouded in eternal night." *

228. *The Existence of the Sea depends upon great Internal Heat.*—It is now the general opinion of both astronomers and geologists, that the interior of the earth must be possessed of a temperature exceeding anything we know of calorific emanations on its surface; and that it is this intense heat, whether maintained by solid or liquid matter, which holds together the inner particles of the external crust, otherwise the roof of the crust would shrink and crack at a low temperature, and the sea sink through the deepest or thinnest parts of its bed. It has been calculated that "If a channel only three quarters of a square mile in sectional area were opened from the bottom of the sea to the centre of the earth, the whole ocean would flow into it—taking, that is to say, the increase of density of water (according to the experiments of Perkins) at 0.474 per cent for every additional 100 atmospheres of pressure, and supposing the same ratio to hold good under all pressures. This, of course, cannot be supposed to be really the case. One of two things must happen, either the water would be compressed into solidity, or must be sustained from so doing by

* J. Norman Lockyer, in 'The Heavens.'

an increased elasticity, the effect of an exceedingly high temperature. This, indeed, we have every reason to believe, really exists within the earth. Not only is it a general fact that the thermometric temperature of the ground does increase in descending, in all regions wherever deep mines have been sunk, or borings executed, at an average rate of about 1° Fahrenheit for every 90 feet of depth; and not only do the phenomena of volcanoes and hot-springs indicate unmistakably the still further increase of heat beyond the reach of artificial excavation, but the fact itself, that the mean density of the globe is so small as 5½, must be held as conclusive evidence of an excessive internal temperature. It is not by solidifying that fluids can escape from further condensation." *

229. *The Sea contains Atoms of all Soluble Minerals and Metals.*—On this head it has been advanced by the same authority, that "As the sea continually receives the drainage of all the land, besides having, in the course of countless ages, washed over and over again the disintegrated materials of successive continents, it must of course hold in solution all the saline ingredients capable of being separated and taken up by such lixiviation in cold water; in fact, in greater or less quantity, every soluble substance in nature—such, at least, whose existences in extremely dilute solution are not incompatible. By far the larger proportion, however, consists of chloride of sodium (common salt), after which occur chlorides and sulphates of magnesia and lime in some considerable abundance. And in much more minute but yet appreciable quantity, occur salts of potash and ammonia, the iodide and bromide of sodium, carbonate of lime, silica, and other matters too numerous to mention. The sulphate and carbonate of lime, and the silica, however minute the percentage of the latter, are yet of vast importance in the economy of animated nature, as furnishing all the lime and silica out of which the shells of mollusca, the structures of the coral and other similar insects, and the shells and cara-

* Art. "Physical Geography," 'Encyclopædia Britannica.'

paces of the silicious infusoriæ, &c., are derived. But besides these saline and earthy ingredients, metallic salts in excessively minute quantities have been shown to exist in sea-water. Thus copper is present to such an extent, that clean and polished iron dragged in the wake of a ship, during even a short voyage, has been observed to come up with a film of that metal precipitated upon it. Silver also is formed in combination with the old and worn coppering of ships to such an amount as to make it worth while to extract it;"* and, as we shall presently see, has been computed at 200 million tons held in chemical solution by the whole ocean.

230. *Analysis of Chemical Ingredients found in Sea-Water.*—We must distinguish here between those ingredients that may be considered primarily in chemical combination with sea-water and others of a secondary character, that mingle in the ocean by means of rains, rivers, currents, waves, and winds, through what may be termed mechanical action. For example, a salt spring carries saline particles to the sea from passing over a stratum of rock-salt originally deposited by the ocean; but it does not follow that all the salt in the sea came from similar land-sources. We take it to be an incontestable fact, that the salts in chemical solution with the pure water, which forms more than nineteen-twentieths of the sea, have been in combination before any land was formed. Moreover, we must distinguish between the soluble and insoluble substances produced by the sea, where the former may combine with their parent element, but the latter, once produced, never return to their primary condition. This is seen in the coral-reefs, that withstand the most powerful attrition of waves and the warm currents of tropical seas for centuries, without a particle of their substance either softening or dissolving. How far the softer formations of chalk and marl may mingle chemically with sea-water we are not prepared to say, but this must be infinitesimal compared with the ingredients inherent in its

* Art. "Physical Geography," 'Encyclopædia Britannica.'

composition. The following is given by M. Regnault as a mean result of the analysis of sea-water :—

Pure water, ...		96.470
Saline ingredients = 3.505,	Chloride of sodium,	2.700
	" magnesium,	0.360
	" potassium,	0.070
	Sulphate of lime, .	0.140
	" magnesia,	0.230
	Carbonate of lime, .	0.003
	Bromide of magnesium,	0.002
Loss (including iodides, silica, &c.), . . .		0.025
		100.000

231. *Primary Bed of the Sea formed of Microscopic Shells.*—To return to the main subject under consideration, regarding the strata forming the bed of the primeval sea. The process of solidification alluded to was of an entirely different nature from these chemical changes. There are ample data for concluding that the great organic law that pervades every drop of the ocean was the first solidifier of the earths and salts which sea-water holds in chemical combination. The most remarkable discoveries on this head have been made by hydrographers only recently in sounding the depths of the ocean, and submitting the particles obtained from its bed, brought up by the sounding-apparatus, to the examination of the microscope. In the hands of Ehrenberg and other skilled *savans*, that instrument has revealed to us the fact that, in the deepest parts of the Atlantic, the Pacific, and the Indian Ocean, their beds are strewed with countless myriads of minute shells, without a particle of sand or gravel being found. Among the foremost men in conducting these oceanic experiments practically is Captain Maury, formerly of the American navy, who received great aid from a fellow-officer named Brooke, the inventor of an ingenious sounding-apparatus, which has reached depths of five and nearly six miles, bringing up specimens of the ocean-bed. On submitting some soundings from a depth of two miles in the basin of the Atlantic to Professor Bailey of America, he pronounced them to be "chiefly made up of perfect little calcareous shells

(*foraminifera*), and contain also a small number of silicious shells (*diatomaceæ*)." Although perfect in form, these minute shells contained no animal life, which led the Professor to conclude "that they inhabit the waters near the surface, and when they die their shells settle to the bottom." This examination elicits the following remarks from Captain Maury :—

232. *Captain Maury's Remarks on the Abundance of Minute Shells and Absence of Sand at the Sea-Bottom.*—"These little mites of shells seem to form but a slender clew indeed by which the chambers of the deep are to be threaded, and the mysteries of the ocean revealed; yet the results are suggestive in right hands, and to right minds they are guides to both light and knowledge. The first noticeable thing the microscope gives of these specimens is, that all of them are animal, not one of the mineral kingdom. The ocean teems with life, we know. Of the four elements of the old philosophers—fire, earth, air, and water—perhaps the sea most of all abounds with living creatures. The space occupied on the surface of our planet by the different families of animals and their remains is inversely as the size of the individual. The smaller the animal, the greater the space occupied by his remains. Though not invariably the case, yet this rule, to a certain extent, is true, and will therefore answer our present purposes, which are simply those of illustration. Take the elephant and his remains, or a microscopic animal, and compare them. The contrast, as to space occupied, is as striking as that of the coral reef or island with the dimensions of the whale. The graveyard that would hold the corallines is larger than the graveyard that would hold the elephants.

233. "We notice another practical bearing in this group of physical facts that Brooke's apparatus fished up from the bottom of the deep sea. Bailey with his microscope could not detect a single particle of sand or gravel among these mites of shells. They were from the great telegraphic plateau; and the inference is, that there, if anywhere, the waters of the sea are at rest. There was not motion enough there

to abrade these very delicate organisms, nor current enough to sweep them about, and mix up with them a grain of the finest sand, nor the smallest particle of gravel torn from the loose beds of debris that here and there strew the bottom of the sea."

234. *Professor Bailey's Remarks on the Animalculæ of these Shells living in the Upper Waters and sinking after Death.*—"As Professor Bailey remarks, the animalculæ whose remains Brooke's lead has brought up from the bottom of the sea, probably did not live or die there. They would have had no light there, and, had they lived there, their frail little textures would have been subjected in their growth to a pressure upon them of a column of water twelve thousand feet high, equal to the weight of four hundred atmospheres. They probably lived and sported near the surface, where they could feel the genial influence of both light and heat, and were buried in the lichen-caves below after death. Brooke's lead and the microscope, therefore, it would seem, are about to teach us to regard the ocean in a new light. Its bosom, which so teems with animal life; its face, upon which time writes no wrinkles—makes no impression—are, it would seem, as obedient to the great law of change as is any department whatever, either of the animal or vegetable kingdom. It is now suggested that henceforward we should view the surface of the sea as a nursery teeming with nascent organisms, its depths as the cemetery for families of living creatures that outnumber the sands on the sea-shore for multitude. Where there is a nursery, hard by there will be found also a graveyard—such is the condition of the animal world. But it never occurred to us before to consider the surface of the sea as one wide nursery, its every ripple as a cradle, and its bottom one vast burial-place."

235. "The geological clock may, we thought, strike new periods—its hands may point to era after era; but so long as the ocean remains in its basin—so long as its bottom is covered with blue water—so long must the deep furrows and strong contrasts in the solid crust below stand out bold,

ragged, and grand. Nothing can fill up the hollows there; no agent now at work that we know of, can descend into its depths and level off the floors of the sea. But it now seems that we forgot these oceans of animalculæ that make the surface of the sea sparkle and glow with life. They are secreting from its surface solid matter for the purpose of filling up the cavities below. These little marine insects are building their habitations at the surface, and when they die, their remains, in vast multitudes, sink down and settle upon the bottom. They are the atoms of which mountains are formed and plains spread out."

236. *All the Limestone Series of Rocks formed of Fossil Zoophyte Remains.*—In confirmation of this statement, geology informs us that there are certain formations in the crust of the earth composed entirely of minute shells. A familiar example of these marine deposits is found in England in the oolitic formation, which is a species of limestone composed of globules clustered together commonly without any visible cement or base. They vary in size from that of small pinheads to that of peas. These globules, on investigation, have been pronounced to be shells of the sea-urchin order, that must have existed in enormous quantities in the primeval sea of Europe. In still more ancient formations, such as the Silurian series of fossil rocks, there is evidence that these were formed of minute zoophytes, which existed in myriads at the earliest geological periods, when the deep-sea formations* were deposited. And recently, in Canada, discoveries have been made of even lower fossil rocks than have been found in Europe, named the Laurentian series, which is considered to be anterior in its formation to some of the primary igneous rocks, so called. This series of strata has been ascertained to be several thousand feet in thickness, and in all probability is part of the bed of the primeval ocean before the upheaval of the land. In examining the structure of these rocks, geologists have a difficulty in pronouncing satisfactorily the nature of their primary composition, as they exhibit evidence of having been metamorphosed by the ac-

tion of the internal heat of the earth and the igneous rocks which burst through them, in many cases amalgamating and forming a distinct rock from either. Every day new light is being thrown upon this interesting branch of geological study by the researches of its zealous students, tending to show that the abundance of animal life in the primeval ocean was as great as, if not greater than, it is at present. It may be satisfactorily proved yet that all the limestone series of rocks, which comprise such a depth and extent of the earth's crust, are solely the result of animal organisms that have extracted their elements from the sea, as we are satisfied that the coal-deposits are entirely of vegetable origin, consolidated by pressure, and acted on by volcanic heat.

237. *The Bed of the Primeval Sea formed probably of Minute Shells.*—There is no necessity to go further into detail; enough has been shown that the primeval sea swarmed with animal life, and their remains sank to the bottom, forming deposits which have been ascertained to be several thousands of feet in thickness. Now, with this fact before us, it is not unscientific to advance the hypothesis that the entire spherical bed of the primary circumambient waters was composed of the earths and salts they held in chemical combination. These minute molluscs were animated laboratories that separated the mineral parts of the ocean from the pure water; and as the fact of their remains being precipitated to the bottom illustrates their greater density, so must the bulk of the primeval sea have decreased, and consequently its general level. What that decrease may have been, of course there are no geological data to show, inasmuch as no land was upheaved above its surface to register its subsidence from a higher level. Since the advent of geological eras, the same process of solidification has been going on, and it is an important branch of research to obtain data that may throw light on the subject. At present our information is chiefly confined to the subsidence of subsidiary seas, which no doubt are also worthy of investigation; but so far as the phenomenon has been observed, the cause has been traced more to the

changes in the level of the coasts than to the seas themselves.

238. *Dr Carpenter's Estimate of the Enormous Increase of Animalcules.*—Of the elevation of sea-beds the most remarkable examples are those where the myriads of coral insects are at work secreting the calcareous ingredients of the ocean, to build up those magnificent structures seen by divers into the waters where they most prevail. "We may here recall what has been stated respecting, the extensive formations of calcareous submarine masses by the labours of the coral insect. Such facts would be utterly incredible but for what we know of the astonishing rapidity of multiplication of these minute forms of animal life. Dr Carpenter computes the progeny of a pair of aphides, if allowed to accumulate, at the end of the year, at a *trillion.* Granting the reproduction of marine animalcules to be *one thousand billions less rapid* than that of aphides—granting that each of them during its lifetime (supposed not interfered with, and food supplied) secreted only a ten-millionth part of a cubic inch of indestructible calcareous matter—we should find accumulated, in less than a quarter of a century, a globe of such material whose diameter would exceed the distance travelled by light since the ordinary received epoch of creation (4004 B.C.): and the surface of the globe, supposed to continue increasing at the same rate, would then be swelling into space a great many times faster than the speed of light. There needs, then, only a residual immunity for a small percentage of those produced to afford scope for the production of all the calcareous formations existing; and the same may be said of all geological formations, such as the polishing slate of Bilin (40,000,000 to the cubic inch !), the infusorial formations in Holland, &c., which microscopic examination has shown to consist of infusorial and other exuviæ." *

239. *Silica, a large Ingredient of the Primeval Sea, now exhausted.*—From the analysis of sea-water, as already mentioned, its mineral constituents held in chemical solution are

* Art. "Physical Geography," 'Encyclopædia Britannica.'

comparatively small to the volume of pure water, and computed generally as follows: chloride of sodium, 2.50; chloride of magnesium, 0.35; sulphate of magnesia, 0.58; carbonates of lime and magnesia, 0.02; sulphate of lime, 0.01; water, 96.54—in 100 parts. Calculating upon this basis, and considering the enormous masses of lime contained in sedimentary rocks of the tertiary period, we may safely infer that the sea, during that epoch, contained in solution a much larger proportion of calcareous matter than at present, if it did not exceed in volume all the other mineral ingredients of the ocean together. Then we may infer that the tertiary zoophytes, in extracting so much of that element from the sea, rendered the water less capable of supporting their constitution, and many species became extinct, while individuals decreased in numbers. In this manner we can understand how the carbonates and sulphates of earths in the sea, which form the imperishable parts of these marine animals and their shells, lessened as the sediment forming the tertiary strata increased; while the chloride of sodium, or common salt, remained comparatively undiminished, in consequence of that mineral being easily soluble in water. On the other hand, we may speculate upon the sea having possessed other mineral ingredients, not specified in the above analysis, during earlier epochs than the one referred to. It is not out of the range of probability that silica once entered even more extensively than lime into the chemical constituents of the sea, as the oxide of silicon; for there is evidence still of its existence in the exuviæ of diatomaceæ and the silicious covering of shells. There are data, also, from the silicious slates of Tripoli, &c., to show that at one period marine zoophytes, whose shells were entirely composed of silex as pure as quartz, existed in such multitudes that, in the course of time, they nearly exhausted the sea of this mineral element, until they became extinct, and were succeeded by lime-secreting molluscs and coral insects.

240. *Crystalline Rocks may have been originally formed of Silicious Shells.*—The consideration of this question opens

up a wide field of inquiry to the speculative geologist. Here he might find a solution to the problem regarding the primary formation of the rocky masses which constitute the lower parts of the crust of the earth, wherein this important mineral forms the characteristic ingredient, such as granite, syenite, porphyry, and quartz rock. May not these have been originally deposited in the form of microscopic silicious shells, which afterwards became crystallised and metamorphosed through the incandescent volcanic heat of the earth? The theory that obtains amongst all classes of speculative philosophers who have considered the question, is based on the chemical principle of precipitation, where solid matter separates from liquid by loss of affinity, and descends in virtue of the law of gravitation. This is perfectly correct as far as secondary silicious rocks, such as the sandstones, are concerned, because these are formed by the abrasion of older rocks; but it is not applicable to the first formation of silex, or as we have observed to that of lime, the basis of the fossiliferous limestone rocks. There is incontrovertible living evidence that the calcareous deposit of coral-reefs is formed by minute insects possessing the function of secreting the lime contained in sea-water; and by comparing these modern deposits with ancient marble formations, it is abundantly evident that they are analogous in structure. Hence it is concluded that every portion of the enormous masses of limestone rocks that enter into the structure of the earth's crust has, at one period or another, passed through living organisms, without whose agency they never would have been extracted from the sea. Pursuing the same line of analysis, it is probable that the basis of all the silicious and argillaceous rocks may have been secreted in a similar manner, each in its turn having been subservient to the purposes of life by entering into the composition of organised bodies.

241. *Speculative Views on Latent Vitality and Spontaneous Generation.*—In like manner the experimental philosopher might settle the much-vexed question among scientific controversialists regarding the phenomena of apparent spontaneous

generation, so zealously disputed by two French *savans* recently—namely, M. Pouchet, the great champion of the theory, and M. Pasteur, its sworn enemy. It might be argued, that as all solid matter on this earth at one period formed a constituent part of some living creature, so does it retain in a latent degree the elements which would again produce life, just as the chemist informs us that every substance contains more or less latent heat. Viewed in this light, inorganic matter would be only comparatively devoid of organic properties, as cold substances, such as ice and snow, are proved to possess latent degrees of heat. Then, again, this latent organic property would increase in degree as the atoms of matter passed through several stages in the scale of animal or vegetable organisation—accumulating this principle until they reached a point where the power of vitality being destroyed in producing a larger and more perfect animal, nevertheless retained sufficient organic fecundity to generate lesser and microscopic infusoria, returning, as it were, to its primary organic form in the sea. Thus would the experimental philosopher show that the whole substance of our planet is more or less impregnated with the elements of life, which are not extraneous to matter itself, but inherent in its composition as a universal law, permeating every atom like the laws of cohesion or gravitation. And thus might he point to the limestone rocks that spread over the earth above and beneath the sea, as secretions of infusoria that would again aid in generating life; and even point to the granitic Alps, covered with perpetual snow, where now no life is seen, as having once lived and moved in the primeval ocean, becoming the debris of multitudinous marine creatures, and still retaining some vital energy.

242. *Sequence of Organic Life traced back into Inorganic Matter.*—When we investigate the minute gradations naturalists have marked on the scale of organised creation, from the lowest to the highest forms of vegetable and animal life, we cannot strictly define each link in the chain of existence, to say where this degree of organic structure begins and where

that ends. Every class, order, family, or individual blends so imperceptibly into one harmonious whole, that all seem more or less mutually dependent on each for their existence; and, as a rule, the lower forms supply the necessary nourishment for the maintenance of the higher. Thus we find the members of the animal kingdom ultimately dependent upon those of the vegetable kingdom for their food, inasmuch as without vegetation no herbivorous animals could exist, and consequently, by their extinction, carnivorous animals would be deprived of subsistence. This rule obtains in the sea also, though not generally supposed; for the number of marine animals that feed upon sea-weed is calculated to be even greater in proportion than of herbivorous animals on land. But that which especially distinguishes the food-supplying inferior animals of the sea are the cases where they obtain nourishment from the sea-water almost alone; for certain species of whales—the monsters of the deep—support their huge forms on these minute zoophytes Here we see a general law in support of the vital principle which pervades the whole organic creation, until it descends to the level of what we term the inorganic world. But may we not pursue the inquiry below that arbitrary level by the same process of inductive reasoning? If it is necessary for the grosser particles of matter to pass through vegetable organisms before they are proper food for animals, may it not be as necessary that these grosser parts should have been secreted by animalculæ in order to refine them from their purely elementary state for that purpose? Thus it may be said that the doctrine of the ancient philosophers—that the vital principle pervaded the whole material universe, from which man himself was an emanation—agrees with these modern inquiries into an abstruse subject.

243. *Saline Solutions discovered in Granite, and Silver in the Sea.*—Apart from these speculative views of a subject which has been one of angry controversy among naturalists from the time of Aristotle, we may allude to a geological fact of some interest bearing upon the aqueous origin of igneous rocks, which has been made out by Mr Sorby. Upon a close

microscopic examination of granite, ground and polished so thin as to be transparent, and then cemented with Canada balsam between two glass plates, he has discovered that this rock contains an immense number of cavities holding water and saline solutions, which must, therefore, have been in a liquid state when the rock was in the process of formation. It must therefore be concluded that granite is not simply an igneous rock, but that it has been formed by the joint action of fire and water. This fact supports the hypothesis we have suggested, that the silicious rocks were originally sedimentary deposits from the sea, through the secretions of marine zoophytes, as abundantly manifested in the formation of limestone rocks. Moreover, it is not at all improbable that the metallic ores which so largely impregnate the mineral veins of silicious rocks, may have had their origin in these substances entering largely into the composition of the minute shells at the epoch of their generation, as we find the beautiful metallic lustre on shells at the present day. In this manner we can imagine how the gold-bearing and silver-bearing quartz-veins originated in the deposition of purely silicious corals and shells specifically rich in these metals. We have no evidence that gold exists in sea-water; but, on the authority of Captain Maury, we learn that the presence of silver has been detected. By examining, in Valparaiso, the copper that had been a great while on the bottom of a ship, the presence of silver, which it obtained from the sea, was detected in it. It was in such quantities as to form the basis of a calculation, by which it would appear that there is held in solution by the sea a quantity of silver sufficient to weigh no less than 200 million tons, could it all, by any process, be precipitated into a separate mass.

244. *Silicious Rocks originally formed the Bed of the Primeval Sea.*—If, on further investigation, it be found that the older crystalline rocks contain elements of aqueous formation, or, as we have suggested, are metamorphosed remains of an original fossiliferous structure, these may be restored to their former geological position as primitive rocks, which

they have lost latterly in the nomenclature of the science. This has arisen on account of some members of the granitoid series having been found above the oldest fossiliferous rocks, which were classed as secondary. Hence Lyell has proposed, as a substitute for *primary*, the term *hypogene*, implying nether-formed. "As applied to rocks, it expresses that they have assumed their form and structure at a depth from the surface, without implying any priority in their formation as to time; whereas the term primary, as applied to rocks, indicates that their formation was prior to that of all others." Without disputing the appropriateness of the new term, we may point out that if the newest of the granite and quartz series bear evidence of being metamorphic rocks of silicious fossil deposits, they are older in time than the most ancient calcareous fossil formations that have not become metamorphosed by heat. Hence the silicious unstratified rocks forming the crust of the earth may with propriety be designated primitive, as in all probability they formed the primary bed of the primeval sea.

CHAPTER XII.

PHYSICAL CONDITION OF THE SEA AND ITS INHABITANTS.

Humboldt's views on the disparity between the areas of the sea and land, § 245.—Superficies of the sea and land computed in British square miles, 246.—Cubic measurement and absolute weight of the sea, 247.—Average depth of the sea estimated by astronomical formula, 248.—Extent, depth, and sea-bottom of the Pacific, 249.—Deep soundings in the Atlantic by English navigators, 250.—Brooke's improved sounding rod for testing the bed of the sea, 251.—Area and depth of the Indian Ocean not correctly ascertained, 252.—Boundaries of the Antarctic Ocean not properly defined, 253.—Area and depth of the Arctic Ocean only approximately known, 254.—Depth of the Mediterranean and profusion of animal life, 255.—Schleiden's description of the beautiful zoophytes and fish in the Indian Ocean, 256-258.—Zoophytes from the Atlantic in the French aquarium at Arcachon, 259.—The earth not an inert mass of matter, but a stupendous shell of extinct life, 260.—Speculative hypothesis on the origin of bright-coloured minerals, 261.—Wonderful coral scenery and animal life in the sea described by Green, the diver, 262.—Captain Cook's account of an amphibious minnow in Australia, 263.—Professor Agassiz finds a land-travelling fish in South America, five miles from water, 264.—M. Dufossé and Mr Couch on the voluntary sounds made by fish, 265, 266.—Instinct of creatures in the sea to rise towards the light and air, 267.—Migration of fish in European waters indicates the seasons of the sea, 268.—Shoals of herring on the coast of Norway irregular in their migratory seasons, 269.—Summer the season of activity among the inhabitants of the sea, 270.—The temperature of the sea decreases in depth from the surface, 271.

245. *Humboldt's Views on the Disparity between the Areas of Sea and Land.*—From the primeval condition of the sea, and its mineral analysis, we now come to consider its present physical geography, and the influence it exercises on the seasons. With regard to the intervening periods, sufficient

has been advanced in the division on the land to furnish a general sketch of its separation into oceans and subsidiary seas, forming a chain of secondary causes and effects, uniting the rudimentary with the complicated phenomena that now exist. According to Humboldt: "In the present condition of the surface of our planet, the area of the solid is to that of the fluid parts as 1 to 2⅘ths (according to Rigaud, as 100 to 270). The islands form scarcely $\frac{1}{22}$d of the continental masses, which are so unequally divided that they consist of three times more land in the northern than in the southern hemisphere; the latter being therefore pre-eminently oceanic. From 40° south latitude to the antarctic pole, the earth is almost entirely covered with water. The fluid element predominates in like manner between the eastern shores of the old and the western shores of the new continent, being only interspersed with some few insular groups. The learned hydrographer Fleurieu, has very justly named this vast oceanic basin, which under the tropics extends over 145° of longitude, the *Great Ocean*, in contradistinction to all other seas. The southern and western hemispheres (reckoning the latter from the meridian of Teneriffe) are therefore more rich in water than any other region of the whole earth. These are the main points involved in the consideration of the land and sea—a relation which exercises so important an influence on the distribution of temperature, the variations in atmospheric pressure, the direction of the winds, and the quantity of moisture contained in the air, with which the development of vegetation is so essentially connected. When we consider that nearly three-fourths of the upper surface of our planet are covered with water, we shall be less surprised at the imperfect condition of meteorology before the beginning of the present century; since it is only during the subsequent period that numerous accurate observations on the temperature of the sea, at different latitudes and different seasons, have been made and numerically compared together. . . . . The word climate certainly has special reference to the character of the atmosphere, but this character is itself dependent

on the perpetually concurrent influences of the ocean, which is universally and deeply agitated by currents having a totally opposite temperature, and of radiation from dry land, which varies greatly in form, elevation, colour, and fertility, whether we consider its bare rocky portions, or those that are covered with arborescent or herbaceous vegetation."

246. *Superficies of the Sea and Land computed in British square miles.*—Computations have been made of the entire superficies of the earth at the sea level according to the British scale of measurement, which give a total of 196,663,400 statute square miles. This, of course, supposes that all the mountainous regions are level with the water, and furnishes us with the area of the primeval sea before the land rose above its surface. Of its division into land above the level of the sea, and the area of the sea itself in its continuous ramifications around the land, only approximate estimates can be formed, in consequence of its unexplored regions at the poles and elsewhere. As far as the latter can be ascertained, hydrographers have calculated its superficies, including all the inland seas, at 146,863,400 square miles. The most remarkable general feature which the sea presents to the physical geographer is its *continuity*. Excepting the Caspian Sea, with its completely land-locked shores, which is more a vast lake than a sea, the oceanic waters encompass the globe from pole to pole, and embrace both hemispheres in their sinuous arms, encircling every continental mass and island.

247. *Cubic Measurement and Absolute Weight of the Sea.*—"From a careful measurement of its extent, as laid down in charts, it has been concluded that the dry land occupies a superficies of about 49,800,000 square statute miles. This does not include the recently-discovered tracts of land in the vicinity of the poles; and, allowing for yet undiscovered land (which, however, can only exist in small quantity), if we assign 51 millions to the land, there will remain about 146 millions of square miles for the extent of surface occupied by the ocean. Its mean depth, of course, cannot be stated with any certainty. There are phenomena in the formation and

progress of the tidal wave, and of certain other great undulatory movements, which are incompatible with an average depth under four or five miles. Most of the soundings which have been taken far from land, and in deep water, fall, however, far short of these limits; but as some have obtained the higher of them, and as there are numerous instances when twenty, thirty, forty, and even fifty thousand feet of line run out have failed to give distinct evidence of the bottom having been reached, a *mean* depth of four miles may be taken as one quite as near the truth as five miles; the more *so*, as a great proportion of the vast area of the Pacific is so abundantly bestrewn with islands as to authorise a reasonable suspicion that its average depth is less than that of the Atlantic, where islands are comparatively rare, and of which the depth has been ascertained over no inconsiderable portion of its whole extent. Calculating on these data, we find, for the total cubic contents of the sea, 788 millions of cubic miles, and for its mass or weight (taking the specific gravity of sea-water under a pressure of two miles at 1.0151) 3,270,600 billions of tons, or $\frac{1}{1768}$th part of the total mass of the globe." *

248. *Average Depth of the Sea estimated by Astronomical Formula.*—Besides the practical method of using improved sounding-apparatus to ascertain the depth of the ocean, astronomers have a formula showing that there exists a relation between the breadth of a wave, its velocity of progress, and the depth of the water on which it travels, whereby they can compute the average depth of the great oceans. On this basis Professor Airy has constructed a table, by which Professor Bache came to the conclusion that, in the North Pacific, between Japan and California, the mean depth is 2365 fathoms, or 14,190 feet. His observations were taken during a great wave caused by an earthquake in Japan, which traversed the ocean to the American coast. "By a similar principle of calculation, grounded on the progress of the tide-wave (regarded as a free wave) running up the Atlantic—viz., that a wave 6000 geographical miles in breadth from

* Art. "Physical Geography," 'Encyclopædia Britannica.'

east to west travels its own breadth in twelve hours*—we find, for the *mean* depth of the whole Atlantic, from 50° south lat. to 50° north, 22,157 feet, a result perfectly in accordance with what we know from numerous soundings of its northern basin, and what may reasonably be concluded from the comparatively few obtained in its southern basin."

249. *Extent, Depth, and Sea-Bottom of the Pacific.*—The Pacific Ocean is the most extensive of the great hydrographical divisions of the world, extending from the arctic circle at its northern boundary to the antarctic circle in the south hemisphere over 133° of latitude; and from the west coast of America to Australia in the south, and Asia in the north division, over nearly 160° of longitude, covering an area estimated in round numbers at 50,000,000 square miles. Its depths have been only partially sounded, the most interesting being those obtained with the apparatus invented by Lieutenant Brooke, U.S.N., for the purpose of ascertaining the nature of the sea-bottom. The deepest of these soundings was taken in the North Pacific, near Behring Strait, where the bottom is at 16,200 feet, and consists chiefly of microscopic silicious shells, named *diatomaceæ*, "which are in a remarkable state of preservation, frequently with the valves united, and even retaining the remains of the soft parts." This statement of Professor Bailey of New York, who examined the specimens, is evidence that the sea contains silica in solution, although chemists have not detected its presence by analysis. Specimens from the South Pacific, obtained from the bed of the coral sea at a depth of 12,900 feet, were pronounced by the same authority to yield representatives of most of the groups of microscopic organisms usually found in marine sediments, the predominant forms being silicious spicules of sponges, with a few diatoms, and only one perfect shell of foraminiferæ. This test of the ocean-bed by deep-sounding differs considerably from those obtained in the Atlantic, which were almost wholly composed of the latter genus, and of a calcareous nature, while the former were mostly silicious. "This only makes the condition of things

in the northern Atlantic the more interesting; because," remarks Professor Bailey, "they prove that deep water is not necessarily underlaid by foraminiferous deposits, and that some peculiar local conditions of temperature, currents, or geological substratum, have made the North Atlantic a perfect vivarium for the calcareous forms." May this condition not arise from the presence of silica and silicious-secreting zoophytes in the South Pacific, as living remnants of extinct *diatomaceæ*, whose shells enter chiefly into the composition of the silicious rocks forming the lower crust of the earth?—a hypothesis suggested by our speculative remarks on the primary formation of granite and quartz rock before they were metamorphosed by volcanic heat. It is worthy of remark here, that most of the corals found in the Coral Sea, near the Australian shores of the Pacific, are analogous to the species of madrepores, forming the most numerous fossils of the ancient limestone rocks; also some species of shells allied to the extinct genus of *terebratula*.

250. *Deep Soundings in the Atlantic by English Navigators.*—The Atlantic Ocean occupies only half the superficial extent given to the area of the Pacific, and is estimated at 25,000,000 square miles—the two forming hydrographical divisions in the aggregate rather more than all the other oceans and subsidiary seas together. It extends 8600 miles from north to south, and its breadth varies from 1800 to 5400 miles. Of all the oceans this is best known in its physical phenomena, and its bed has been accurately sounded to the greatest depths known in the sea generally. "Thus, Captain Sir Edward Belcher, R.N., in lat. 0° 4′ N., long. 10° 6′ W., sounded to the depth of 3065 fathoms = 18,390 feet; Captain Barnett, R.N., in lat. 41° 2′ N., long. 44° 3′ W., sounded to the depth of 3700 fathoms, or 22,200 feet; Captain Sir James Ross, R.N., in 1840, to 2677 fathoms, or 16,062 feet; and afterwards in lat. 33° 3′ S., long. 9° 1′ E., to 4600 fathoms, or 27,600 feet; and Captain Denham, H.M.S. Herald, has obtained soundings at the vast depth of 7706 fathoms = 46,236 feet, or about 8¾ English miles.

This, which is the deepest sounding ever yet taken, occurred on the 30th October 1852, in lat. 36° 49′ S., long. 37° 6′ W.* There are doubts as to the accuracy of this last depth, as it is supposed the line may have been extended horizontally by the currents. To check this error, the plan now adopted is to time the descent of the weight attached to a line always of the same thickness and make, by which means it can be ascertained when the sinker ceased to carry the line out, which it does at a decreasing rate from oceanic pressure, while currents do so at a uniform rate. This check upon errors of deep sounding was established by Maury and other hydrographers; and on testing the soundings of British hydrologists, there was evidence showing that these were not so great as report had made them to be. With the improved apparatus and correction by time, two hundred soundings have been made by officers of the American navy, from which a chart of the North Atlantic basin has been constructed, showing its greater depths from 1000 to 5000 fathoms, and the general form of this great ocean valley.

251. *Brooke's improved Sounding Rod for testing the Bed of the Sea.*—It was here especially that Brooke's sounding-rod brought up the remains of infusoria, showing that the Gulf Stream has literally strewed the bottom of the Atlantic with these microscopic shells. Their unabraded appearance, "and the almost total absence of the mixture of any detritus from the sea or foreign matter, suggest most forcibly the idea of perfect repose at the bottom of the deep sea. Some of the specimens that Brooke's apparatus has brought up are as pure and free from the sand of the sea as the snow-flake that falls, when it is calm, on the lea, is from the dust of the earth. Indeed these soundings suggest the idea that the sea, like the snow-cloud with its flakes in a calm, is always letting fall upon its bed showers of these microscopic shells; and we may readily imagine that the 'sunless wrecks' which strew its bottom are, in the process of ages, hid under this fleecy covering, presenting the

* 'Encyclopædia Britannica,' art. "Atlantic Ocean."

rounded appearance which is seen over the body of the traveller who has perished in the snow-storm. The ocean, especially within and near the tropics, swarms with life. The remains of its myriads of moving things are conveyed by currents, and scattered and lodged in the course of time all over its bottom. This process, continued for ages, has covered the depths of the ocean as with a mantle, consisting of organisms as delicate as the macled frost, and as light as the undrifted snow-flake on the mountain."*

252. *Area and Depth of the Indian Ocean not correctly ascertained.*—The Indian Ocean comprises all that hydrographical division between the Antarctic Ocean in the south hemisphere and the shores of the Asiatic continent in the north—an extent of about 6500 miles of latitude—and from the African coast on the west to the Australian shores on the east, ranging from 6000 to 4000 miles between the coast of Arabia and that of Malacca. North of the equator its shores are rendered very irregular by the great Asiatic peninsulas of Arabia and Hindostan, around which its branches form the Red Sea, the Persian Gulf, and the Bay of Bengal. The area of the Indian Ocean is estimated at 20,000,000 square geographical miles. Its greatest depths have not yet been ascertained with such a degree of correctness as to entitle them to the same confidence as the deep soundings of the Atlantic. At the same time there are data for concluding that these are equally profound. On one occasion, when an American surveying ship was in the deep waters of this ocean, Lieutenant Brooke cast his ingenious sounding-rod, which run out the line to the enormous length of 7040 fathoms, or 42,240 feet, when it touched the bottom. Unfortunately, however, the line broke, and the testing-apparatus was lost, so that the nature of the ocean-bed could not be ascertained. This was to be regretted, as he reports that "such opportunities are rare in that locality; yet, owing to the current of sixty miles, it will be a difficult matter to determine its absolute depth. That current was not as super-

* 'Physical Geography of the Sea,' by M. F. Maury.

ficial as one might at first suppose, for it was during the latter part of the operation that the boat experienced its effect, and it would seem that, had the current been superficial, the line would have given indication by tending ahead, whereas it ran right down. Moreover, that current was local, which adds to the probability of its depth." Allowing an error of 2240 feet for the current, and adding this depth to the highest peak of the Himalayas above the sea-level, we have here a vertical elevation of land not less than thirteen miles in perpendicular height, or 68,640 feet, forming $\frac{1}{304}$th part of the earth's radius, at its mean diameter of 7912 miles. As these soundings are extended into the higher latitudes of the Indian Ocean, where the sea enters the grand southern extra-circumpolar depression of the earth, greater depths in all probability will be reached.

253. *Boundaries of the Antarctic Ocean not properly defined.*—The Antarctic Ocean comprises all the area beyond the southern latitudes referred to, and forming a superficial radius round the south pole of 23° 28′, or 1408 miles, presenting a circle of the earth's surface having a diameter of 2816 miles, and an approximate area of 6,000,000 square geographical miles. From this it will be seen that the boundary of this so-called ocean is quite arbitrary, and has no exact definition compared with the land, as a line of coast that eminently belongs to other great hydrographical divisions of the sea. According to the natural definition of its waters, they are merely the southern prolongations of the Atlantic, Pacific, and Indian Oceans, which in themselves are only separated by imaginary meridian lines, until they lave the ice-bound shores of the south polar continent. Few navigators have penetrated beyond the arbitrary boundary of this *quasi* ocean, in latitude 66° 32′. The first distinguished explorer was Captain Cook, who reached 71° 10′ 30″ S. lat., in 107° E. long., on January 30, 1774; and among the latest is Sir James Ross, who traced the shores of the great south Victoria Land from lat. 71° to nearly lat. 78°; and on February 2, 1841, reached 78° 10′ S. lat., in 167°

27′ W. long., when his further progress was arrested by a barrier of ice, presenting a perpendicular face of 150 feet in height, and far overtopping the ship's masts. It would appear, from the soundings made during this expedition in the ships Erebus and Terror, that the seas in that region are comparatively shallow. These rarely exceeded 400 fathoms, or 2400 feet, being more frequently from 1200 to 1800 feet, as the sounding-apparatus was cast in higher latitudes. This would indicate a gradual shallowing of the sea in the southern circumnavigable waters, thereby supporting the theory of a south polar continent, and illustrative of our hypothesis that the submarine levels of the land in these regions taper suddenly towards the pole, which we have compared to the narrow end of a lemon.

254. *Area and Depth of the Arctic Ocean only approximately estimated.*—The Arctic Ocean is a well-defined hydrographical division of the universal sea, with its shores clearly marked out by the extremities of the continents of Europe, Asia, and America. In this respect its features are quite the opposite of those presented by the assumed counterpart at its antipodes; while of the great oceans it is the most enclosed by land. In describing its boundaries, geographers cast aside the imaginary line of the arctic circle, and delineate its area by the coast-lines, which in some places are within, and in others without, that circle, where it is united to the Pacific by Behring Strait, and to the Atlantic by a wide channel between Greenland and Norway. Although none of the many intrepid navigators who have explored this inhospitable region have penetrated to the north pole, or crossed the highest latitudes from east to west, yet there are sufficient data to infer from their observations that a polar sea exists, only that its waters are ice-bound during the greater part of the year. "The Arctic Ocean freezes even in summer; and during the eight winter months a continuous body of ice extends in every direction from the pole, filling the area of a circle between 2000 and 3000 miles in diameter." The area of this ocean may be estimated at from 4,000,000 to 5,000,000

square geographical miles; but no minute computation has been ventured upon by hydrographers, as the unexplored regions still form a considerable blank on their charts. Dr Kane sounded in Baffin Bay near its axis, and found 1900 fathoms = 11,400 feet. Of its greatest depths we are not furnished with any soundings by the navigators who penetrated furthest into its central latitudes. It would appear that their efforts in exploring its superficies were so perilous over the fields of ice which covered the ocean, that this barrier, and want of time, prevented sounding the deepest parts. Wherever the water was crossed in shallow parts, it appeared extremely pure, shells being distinctly visible at a depth of 480 feet. It also presented rapid transitions of colour, chiefly from ultramarine to olive green—the latter produced by the presence of myriads of marine animals.

255. *Depth and Profusion of Animal Life in the Mediterranean.*—In this outline of the leading features presented by the five great hydrographical divisions of the world, enough has been advanced to furnish a comprehensive view of the sea without entering into separate descriptions of the subsidiary and inland seas not included in these computations. Suffice it to say, that the aggregate area of the Mediterranean, Caspian, Baltic, and Black Seas, is estimated at not more than 2,291,600 square geographical miles. Of these seas the Mediterranean is the deepest, being 6000 feet at one spot where the telegraph cable lies at the bottom, between the island of Corfu and Otranto in Italy; and at a point midway between Malta and Crete, Captain Spratt sounded to a depth of 2300 fathoms = 13,800 feet—the soundings bringing up the usual calcareous shells of *foraminifera*, but few or none of silicious *diatomaceæ*. Here, also, is an instance of the extraordinary productiveness of sea-waters; and the productions of the Mediterranean are generally of a more tropical character than those of the lands which abut on its shores. "The countless numbers of the larger spinaceo-finned fishes sporting near the surface, which makes the Mediterranean gay with the tint of every colour, the lustre of every metal,

and the glow of every gem—the groves of precious coral—the multitudes of crustacea, mollusca, and all the other productions of the deep—all tend to make this inland sea one of the wonders of nature; and there is really nothing in the same latitudes of the Atlantic or the Pacific that can vie with it." From this we infer that in these land-locked waters we have the remaining species of the tropical era in Europe that inhabited more northern seas, but which have become extinct or migrated to the present tropical oceans. Of their resplendent beauty, as exemplified in existing species, no one has furnished such a graphic description as the German naturalist Schleiden, in his published lectures, from which we quote the following passages, translated in Maury's 'Physical Geography of the Sea':—

256. *Schleiden's Description of the beautiful Zoophytes and Fish in the Indian Ocean.*—"We dive into the liquid crystal of the Indian Ocean, and it opens to us the most wondrous enchantments of the fairy tales of our childhood's dreams. The strangely-branching thickets bear living flowers. Dense masses of *meandrinas* and *astræas* contrast with the leafy, cup-shaped expansions of the *explanarias*, the variously ramified *madrepores*, which are now spread out like fingers, now rise in trunk-like branches, and now display the most elegant array of interlacing branches. The colouring surpasses everything; vivid green alternates with brown or yellow; rich tints of purple, from pale red-brown to the deepest blue. Brilliant rosy, yellow, or peach-coloured *nullipores* overgrow the decaying masses, and are themselves interwoven with the pearl-coloured plates of the *retipores*, resembling the most delicate ivory carvings. Close by, wave the yellow and lilac fans, perforated like trellis-work, of the *gorgonias*. The clear sand of the bottom is covered with the thousand strange forms and tints of the sea-urchins and star-fishes. The leaf-like *flustras* and *escharas* adhere like mosses and lichens to the branches of the corals; the yellow, green, and purple-striped limpets cling like monstrous cochineal insects upon their trunks. Like gigantic cactus-blos-

soms, sparkling in the most ardent colours, the sea-anemones expand their crowns of tentacles upon the broken rocks, or more modestly embellish the flat bottom, looking like beds of ranunculuses. Around the blossoms of the coral shrubs play the humming-birds of the ocean--little fish sparkling with red or blue metallic glitter, or gleaming in golden green, or in the brightest silvery lustre.

257. "Softly, like spirits of the deep, the delicate milk white or bluish bells of the jelly-fishes float through this charmed world. Here the gleaming violet and gold-green Isabelie, and the flaming yellow, black, and vermilion-striped coquette, chase their prey; there the band fish shoots, snake-like, through the thicket, like a long silver ribbon, glittering with rosy or azure hues. Then come the fabulous cuttle-fish, decked in all the colours of the rainbow, but marked by no definite outline, appearing and disappearing, intercrossing, joining company and parting again, in most fantastic ways; and all this in the most rapid change, and amid the most wonderful play of light and shade, alternated by every breath of wind and every slight curling of the surface of the ocean. When day declines, and the shades of night lay hold upon the deep, this fantastic garden is lighted up in new splendour. Millions of glowing sparks, little microscopic medusas and crustaceans, dance like glow-worms through the gloom. The sea-feather, which by daylight is vermilion-coloured, waves in a greenish phosphorescent light. Every corner of it is lustrous. Parts which by day were dull and brown, perhaps, and retreated from the sight amid the universal brilliancy of colour, are now radiant in the most wonderful display of green, yellow, and red light; and to complete the wonders of the enchanted night, the silver disc, six feet across, of the moon-fish, moves, slightly luminous, among the crowd of little sparkling stars.

258. "The most luxuriant vegetation of a tropical landscape cannot unfold as great wealth of form, while in the variety and splendour of colour it would stand far behind this garden-landscape, which is strangely composed exclu-

sively of animals, and not of plants; for, characteristic as the luxuriant development of vegetation of the temperate zones is of the sea-bottom, the fulness and multiplicity of the marine fauna is just as prominent in the regions of the tropics. Whatever is beautiful, wondrous, or uncommon in the great classes of fish and echinoderms, jelly-fishes and polypes, and molluscs of all kinds, is crowded into the warm and crystal waters of the tropical ocean—rests in the white sands, clothes the rough cliffs, clings, where the room is already occupied, like a parasite upon the first comers, or swims through the shallows and depths of the elements—while the mass of vegetation is of a far inferior magnitude. It is peculiar in relation to this, that the law valid on land, according to which the animal kingdom, being better adapted to accommodate itself to outward circumstances, has a greater diffusion than the vegetable kingdom—for the polar seas swarm with whales, seals, sea-birds, fishes, and countless numbers of the lower animals, even where every trace of vegetation has long vanished in the eternally frozen ice, and the cooled sea fosters no sea-weed—that this law, I say, holds good also for the sea, in the direction of its depth; for when we descend, vegetable life vanishes much sooner than the animal, and even from the depths to which no ray of light is capable of penetrating, the sounding-lead brings up news at least of living infusoria."

259. *Zoophytes from the Atlantic in the French Aquarium at Arcachon.*—Our more northern temperate seas are not inhabited by such gorgeous-coloured zoophytes as those existing in tropical oceans; but in the south of Europe, on the Atlantic, many beautiful forms and colours are to be found. At Arcachon, in France, situated on "Biscay's sleepless bay," the largest aquarium in Europe has been constructed, containing specimens of the most interesting creatures of the wondrous deep. As it is situated on the sea-coast, certain species which could not bear being conveyed from place to place inland may be found in it, brought directly from the sea. Among the strangest tenants of this watery palace, the

physalis pelagica, of the same family as what is commonly called the "Portuguese man-of-war," holds the first rank. Its body consists of a large air-sac of a beautiful bluish mother-of-pearl tinge, and surmounted with a crest presenting the various hues comprised between a purple and a brilliant red. From the body there issue splendid blue peduncles, ending in violet tassels, composed of little filaments, each of which is in constant motion; also long spiral fibres, constantly going up and down, and others formed of transparent pearls, presenting all the colours of the rainbow. Next to this most curious and elegant creature, the cuttle-fish may be seen, with its elephant's head and undulating mantle of various hues; and another strange zoophyte, with its head like a hare, and its fins bordered with purple. The task would be too long to enumerate all the strange denizens of the deep that have found hospitality at Arcachon, such as rays, torpedoes, sea-horses, sea-spiders, and other curious creatures typical of animated nature on shore. Thus the sea spider cuts off a leaf from some aquatic plant at hand, chews it into a pulp, and afterwards puts the latter on his back. The consequence is that his prey, seeing this green stuff, which it takes for an island or a tuft of grass, gets upon it, and the moment after has cause to repent its act.

260. *The Earth not an inert mass of Matter, but a stupendous shell of Extinct Life floating in Space.*—Equally curious in form, and sometimes as brilliant in colour, are the countless myriads of *infusoria*, when viewed under the power of the microscope; so that probably the larger forms of zoophytes are derived from their minute progenitors, the species being augmented and altered in the course of time and by the influence of local causes. And these zoophytes themselves, bearing such extraordinary resemblances to elephants, horses, hares, and other land animals, may have been the typical forms created in the primeval sea from which they sprung. When we connect this suggestive idea with what has been shown of the fact that extensive formations in the earth's crust are composed of the remains of *infusoria*, *diatomaceæ*, and other zoophytes, we cannot look upon "our common earth" as the

inert mass of matter which the old astronomers and chemists would have us believe her to be. Here a new and living history is opened up to our contemplation that enhances our veneration for the primary constitution of the world when it emanated from the hands of the Creator. If some rocks can be proved beyond a doubt to have been formed by the labours of marine living creatures, where is the contrary evidence that every formation of the earth's crust did not emanate primarily from the same source, and afterwards became metamorphosed by reason of their own pressure generating the heat that subsequently produced the eruptive forces? This is a question that might be enlarged upon, but not here, as it is in a measure foreign to the subject in hand. Sufficient, however, has been advanced to show that the land which aids so materially in producing vegetable and animal life, is not altogether a mere lifeless deposit of the elements. Viewed in this light, it is the cemetery of those countless myriads of marine creatures of exquisite beauty that rendered the waters of the primeval sea a mass of living *tentaculæ*, surrounding the outer shell, making the world, as it were, a stupendous *encrinite* floating in the boundless ether of the universe. In this light also we may view the rocks as containing the bright elements of colour that dazzled the waves at night, or glowed in the sunlight of the pristine ocean. When we see the various hues that streak the rocks, and glitter in the mineral world, perhaps these are the remains of the bright tints extracted from the sea by the primitive molluscan laboratories. Even the brightest gems found in its dull rocky matrix may have derived their brilliancy from the pigments originally obtained from the ocean, through the alembics of zoophytes, molluscs, or brilliant-scaled fishes.

261. *Speculative Hypothesis on the Origin of Bright-coloured Animals.*—Here the speculative chemical philosopher might trace some affinity between the bright tints of the mineral world and the brilliant colours of zoophytes, testacea, and crustacea, especially those inhabiting tropical seas—realising, in some measure, the poet's idea, that

> "Full many a gem of purest ray serene,
> The dark unfathomed caves of ocean bear"—

with this addendum, that it is possible their beauty may have been derived originally from the sea itself. He might argue that though the scales of fishes reflect the rays of light, in most cases, like the evanescent rainbow-hues of the spectrum, the colours of marine creatures indicate the existence of a pigment, extracted by the animal from sea-water, and may become a chemical constituent in the body of a *zoophyte* or a crustacea. On these grounds he might inquire if, among the exuviæ of the countless myriads of bright coloured marine animals that formed the limestone rocks, their pigments have not entered into the beautiful crystals of fluor-spar and other calcareous minerals. Or, going further back to the theory that silicious rocks are the metamorphosed exuviæ of extinct molluscs, diatoms, and crustaceans, having silex as the basis of their structure, he might thus account for the colouring matter of the amethyst, the topaz, the emerald, the ruby, and other coloured gems being derived from analogous sources. If he were told that this was a far-fetched hypothesis, he might point to the pearl as a pure product of the sea, presenting the lustre and beauty of a gem without metamorphosis by heat. As evidence that in the profound depth of the ocean there exist myriads of bright-coloured creatures where formerly it was supposed none could be found, he might point to the recent dredging operations on the American coast, where, at a depth of more than 3000 feet, some beautiful zoophytes and crustaceans have been fished up, proving that "animal life exists at great depths in as great diversity, and as great an abundance, as in shallow water." Also, "that so far from being lifeless, the deep sea-bottom teems with animal life and with creatures of a very remarkable kind, some of which connect long past geological periods with the *geological* action going on in our own time." *

262. *Wonderful Scenery and Life in the Sea described by Green, the Diver.*— The remarkable analogy between the forms

* 'Athenæum,' December 1868.

of sea and land *fauna* and *flora* is every day being more and more illustrated as our researches penetrate into the depths and shallows of the ocean, and the estuaries of mighty rivers. Among the practical investigators of submarine regions, Mr Green, the famous diver, furnishes some graphic descriptions of what he has seen in the clear waters of the Atlantic, among the West India islands, as follows:—"The banks of coral on which my divings were made are about forty miles in length, and from ten to twenty in breadth. On this bank of coral is presented to the diver one of the most beautiful and sublime scenes the eye ever beheld. The water varies from ten to one hundred feet in depth, and is so clear that the diver can see from two to three hundred feet in depth when submerged, with little obstruction to the sight. The bottom of the ocean, in many places on these banks, is as smooth as a marble floor; in others, it is studded with coral columns from ten to one hundred feet in height, and from one to eighty feet in diameter. The tops of those more lofty support a myriad of pyramidal pendants, each forming a myriad more, giving a reality to the imaginary abode of some water-nymph. In other places the pendants form arch after arch; and as the diver stands on the bottom of the ocean and gazes through these into the deep winding avenue, he feels that they fill him with as sacred an awe as if he were in some old cathedral which had long been buried beneath 'old ocean wave.' Here and there the coral extends even to the surface of the water, as if those loftier columns were towers belonging to those stately temples now in ruins. There were countless varieties of diminutive trees, shrubs, and plants in every crevice of the corals where the water deposited the least earth. They were all of a faint hue, owing to the pale light they received, although of every shade, and entirely different from plants I am familiar with that vegetate on dry land. One in particular attracted my attention; it resembled a sea-fan of immense size, of variegated colours, and of the most brilliant hue. The fish which inhabit these silvery banks I found as different in kind as the scenery was varied. They were of

all forms, colours, and sizes—from the most symmetrical to the globe-like sun-fish; from those of the dullest hue to the changeable dolphin; from the spot of the leopard to the hues of the sunbeam; from the harmless minnow to the voracious shark. Some have heads like squirrels, others like cats and dogs; one of small size resembled a bull-terrier. Some darted through the water like meteors, while others could scarcely be seen to move. To enumerate and explain all the various kinds of fish which I beheld while diving on these banks would, were I naturalist enough so to do, require more space than my limits would allow; for I am convinced that most of the kinds of fish which inhabit the tropical sea can be found there (Hayti). The sun fish, the saw fish, white shark, blue or shovel-nosed sharks, were often seen. There were also fish that resembled plants, and remained as fixed in their position as a shrub. The only power they possessed was to open and shut when in danger."

263. *Captain Cook describes an Amphibious Minnow in Australia.*—In this submarine domain it requires no stretch of imagination to trace the links of the animal creation in their progressive development from the sea to the land,—how gill-respiring fishes emerging from the water have leapt on shore, until, in the lapse of ages, their species changed into lung-breathing animals. Such a transition state is described by Captain Cook in his 'Voyage of Discovery in Australia,' where, on the shores of the Coral Sea, he, and his scientific coadjutors, Sir Joseph Banks and Dr Solander, discovered previously unknown marine and land animals—among others the kangaroo—typical of the extinct *fauna* of Europe, and forming a missing link in the great chain of organised creation. The amphibious fish referred to he describes as follows:—"We found here a small fish of a singular kind. It was about the size of a minnow, and had two very strong breast,-fins. We found it in places that were quite dry, where we supposed it might have been left by the tide; but it did not seem to have become languid by the want of water, for upon our approach it leaped away, by the help of the

breast-fins, as nimble as a frog. Neither, indeed, did it seem to prefer the water to the land; for when we found it in the water it frequently leaped out, and pursued its way upon dry ground. We also observed that when it was in places where small stones were standing above the surface of the water at a little distance from each other, it chose rather to leap from stone to stone than to pass through the water; and we saw several of them pass entirely over puddles in this manner till they came to dry ground, and then leap away."

264. *Professor Agassiz finds a Land-travelling Fish in South America five miles from Water.*—Recent researches of naturalists have led to the discovery of fishes in a still more advanced stage of development from a water-respiring to an air-breathing state. Professor Agassiz informs us "that, on the Amazon river in South America, he found an extraordinary fish, that had the power of walking or creeping on dry land, one having been discovered five miles distant from water. The Professor himself kept one of them out of the water half a day, and on putting it back into its natural element it showed as much life as if it had never been removed. Moreover it is an agile fish, worming its way up the inclined plane of the trunk of some old tree that had fallen, and twisting about among the branches, until finally a single shot has brought down a bird and a fish together. Thus the fish and the bird, with their connecting link the reptile, at first sight so different in appearance, and so apparently separated by a great gulf in structure as well as in habit, are found to grow nearer to each other the better they are understood. It is by tracing points of resemblance, of too technically anatomical a character to be referred to in detail, that Professor Huxley expresses the decision of comparative anatomists when he speaks of the class of birds as 'an extremely modified and aberrant reptile type;' and if the general reader will take for granted the connection between reptiles and birds, he will have no difficulty, from a slight knowledge of frogs in their tadpole and gill-breathing state, in carrying the argument

further, and connecting reptiles, through the amphibia, with fish."*

265. *M. Dufossé and Mr Couch on the Voluntary Sounds made by Fish.*—Besides this extraordinary power of locomotion on land by certain species of fishes, there are some which exercise a vocal power in a remarkable degree. On this interesting subject a French *savant*, M. Dufossé, recently addressed the Academy of Sciences at Paris, laying down the following propositions:—"The muscles of certain fishes have the power of vibratory motion by contraction. This motion is the cause of the sounds which these fishes emit. The noise which lyræ, umbrinæ, and hippocampi make are voluntary. The muscular vibrations which are manifested in the two latter when young, and in a perfectly normal state, abundantly prove that the vibrations observed in these species when subjected to vivisection are normal and physiological, and not owing to a secondary nervous action. The vibrations of the muscles are strengthened by being transmitted to a pneumatic bladder, which increases their intensity. Nevertheless some of the acoustic phenomena emitted by hippocampi are the result of vibrations not intensified by that bladder; so that here there is an instance of muscular motion producing sounds in a vertebrated animal without the aid of any organic auxiliary. In the above species, both males and females have the faculty of emitting sounds, and this faculty is most highly developed at the spawning season."

266. Our own countryman, Mr Couch, in his interesting work on British fishes, mentions several species having the capacity of producing vocal sounds. "In the case of the piper (*trigla lyra*)," he says, "several of the fishes of this genus are known to utter obscure grunting sounds when newly taken out of the water, and they continue them at intervals as long as they live." And speaking of the common gurnard, he mentions its social habits, and tells us that sometimes in the fine weather of summer they will as-

* 'The Intellectual Observer.'

semble together in large numbers, and mount to the surface over deep water, with no other apparent object than the enjoyment of the season; and when thus aloft they move along at a slow pace, rising and sinking in the water for short distances, and uttering a short grunt as if in self-gratification."

267. *Instinct of Creatures in the Sea to rise towards the Light and Air.*— If we contemplate the whole arcana of organic nature from the point of view suggested by these researches into the habits and senses of fishes in relation to land animals, we perceive a great principle animating every member of the animal kingdom, from the lowest to the highest organism, that prompts them to rise towards the great source of light and heat, in order to perfect their structure and improve their functions in the glorious light of the sun. Thus the infusorial exuviæ of the deep seas, where not even a ray of light penetrates, are the remains of animalculæ living in illuminated waters, which in time originate larger species, assuming a crustaceous covering, and becoming a submarine insect inhabiting the shallow waters on the sandy shore—a tiny shrimp, the prototype of the locust that flies over the sands of the desert, revelling in the tropical sunlight. Thus, also, another monad of the deep rising to the surface leaps on shore like the Australian minnow, and in time succeeding species find their breast fins become feet, their side-fins become wings, and their gills become lungs, enabling them to mount into the air, and warble forth their praises at the gates of heaven, rejoicing in their glorious transformation from a lower existence in the sunless deep. Thus, even in the vegetable kingdom, there is an inherent principle in plants to rise from underground darkness into the regions of light—from the gloomy cave into the bright realms of day—from the shady forest high up above the umbrageous foliage. Thus it is everywhere we find an instinct in the animal creation that prompts to aspirations in perfecting organisms and their functions; even as man aspires to soar beyond this sublunary sphere, where his existence is finite, to the realms

above, where he hopes to become a dweller under the light of the Infinite.

268. *Migration of Fish in European Waters indicate the Seasons of the Sea.*—From the contemplation of these wonders of the tropical seas we return to the more familiar inhabitants of European waters, and observe in what manner they are affected by the seasons. At the very threshold of our inquiry we are met with the word itself as specially applied to the finny tribe, which ministers so deliciously to our appetites. This fish is *in season*, and that is *not in season*—signifying that there are times and seasons for their spawning, or their appearance or disappearance from our waters. In these respects the migration of fishes partakes of the same instinct as that of birds. There is this difference, however, with regard to the direction in which that migration takes place, from the point of departure in Europe: birds of migratory habits fly to the south after incubation, but fish of this nature swim towards the north after spawning; while the distances to which fish migrate are not nearly so great as those of birds. Many erroneous views on this head, formerly entertained, have been corrected by the recent observations of indefatigable ichthyologists. For example, it was asserted that the salmon in British waters rushed away to the north pole in their migration. Not only is this totally without foundation, but it has been proved that the habits of the salmon are very local, like those of all other fishes, and it never goes away from the estuary of its own particular stream. Various causes are assigned for the regularity in the migration of salmon from fresh water to salt, and *vice versâ*, among which it is said to be driven from the salt water in consequence of becoming infested with vermin of some kind, which can only be killed by fresh water; and fresh-water lice, on the other hand, impelling it again to seek the sea. Be this as it may, the salmon is brought forward as an example of the regular migration of fish at seasons as marked as the migration of swallows. The return of these beautiful fish from a sojourn in the ocean to their native

streams is one of the natural wonders in animated nature, illustrative of the great law referred to, which impels the lowest class of animals to seek by some mysterious instinct a superior sphere of existence. From the dull depths of the sea the shoals of salmon enter their river-estuary as if rejoicing in their return home to its sunny waters; and in their course they bound over the rocky bed of the stream, or up the rapids, like birds more than fish, their silver-bright scales glittering in the sunshine more brilliantly than the plumage of the feathered creation. It is at such times that man rejoices in the bounty of nature, when he may reap, without the care and trouble of sowing or planting, the most delicious sustenance from the "harvest of the sea," which, in these days of practical knowledge, is becoming as interesting as the harvest of the land.

269. *Shoals of Herring on the Coast of Norway irregular in their Migration.*—The migration of fishes that continually inhabit the deep seas, although regular as to the season of the year, is not so defined as to its area near the land, and, from unknown causes, is sometimes irregular in appearance and numbers. Of this class the common herring is an example, and the history of the fisheries on the coast of Norway furnishes some interesting facts on that head. "Although the fishings on this long range of coast have been abundant during the present century, the fish have been capricious in their appearance at different points along the coast, appearing in some years in large shoals at one spot, and totally abandoning others which for years had been regularly visited. Explanations have not been wanting as to the capriciousness of their migrations, only one of which I will mention, as appearing to me less imaginative than the others—and that is, the belief that the herring shuns places where the year previously large fishings have taken place, because large quantities of dead fish fall to the bottom and infect the water. Instances are given where, in great shoals, masses of dead herring have sunk to the bottom, and where for many years afterwards no shoals have reappeared. One

place in particular near Galten, south-west of Bergen, is pointed out, where one year between 20,000 and 30,000 herrings died from want of room for the shoal, and at which spot no fish has since been seen. The real cause, however, has yet to be discovered, and more probably will be found to be in close connection with submarine agencies, with the abundance or scarcity of food, and with the storms and currents affecting the ocean." * Nevertheless, when the herring does appear after its migration from the coast it is pretty regular, especially in the first season of the year, which lasts from January to March.

270. *Summer the Season of Activity among the Inhabitants of the Sea.*—Although the abundance of animal life inhabiting the deep seas of Europe in winter and spring is something marvellous, yet summer is the season of activity among the fishes and zoophytes found in shallow waters. As the temperature of the sea becomes warmer, and the sun illumines the subaqueous shore, myriads of creatures approach the surface to gambol and revel in the face of day. Unlike the animals and birds on land, that pant and seek for shelter in the heat of the noontide sun, the ocean tribes hold high festival in their watery element. Where the shores are the most destitute of animal or vegetable life the seas are often the most prolific. "When, in the season of drought, the land is parched to the total suspension of all vegetable action, and every animal upon it is faint and languishing, the sea is in the full vigour of growth and life. Even in those parts of the world where the land is perennially and utterly barren, or in such a state as to be quite unavailable for cultivation, and altogether and hopelessly impracticable as the habitation of civilised man, the sterility of the land in nowise invades or affects the sea. Take any locality that you please—the Atlantic on the coast of Sahara, or the Indian Ocean on the barren coasts of Australia—and the sea is as fertile as if the land which it washes were the garden of the globe. The north-west shores of Australia are

* Report of the British Consul on the fisheries of Norway.

barren and irreclaimable; but not so the adjoining waters, for they are redolent of growth and life. The bottom, where it can be seen,—and it is seen to a far greater depth than in our seas, because the almost perpendicular beams of the sun are not so reflected and refracted, but penetrate far into the depths—the bottom, in the number and luxuriance of its productions, and the variety and richness of their colours, emulates a garden of the richest plantation and the highest culture." *

271. *The Temperature of the Sea decreases in Depth from the Surface.*—While the shallow waters of the sea are thus affected at certain seasons by the influence of the sun, the ocean depths are comparatively beyond the direct rays of light and heat. It is calculated that even the tropical seas that maintain the maxima of ocean temperature at the surface, may possess an arctic coldness at their profound depths, thereby in a measure corresponding, only in an inverse ratio, with the decrease of temperature in elevated regions in the air. On this point Humboldt has the following remarks:—"Proceeding upwards and downwards from the common limit of the aerial and liquid oceans, we find that the strata of air and water are subject to determinate laws of decrease of temperature. This decrease is much less rapid in the air than in the sea, which has a tendency under all latitudes to maintain its temperature in the strata of water most contiguous to the atmosphere, owing to the sinking of the heavier and more cooled particles. A large series of the most carefully conducted observations on temperature shows us that, in the ordinary and mean condition of its surface, the ocean, from the equator to the forty-eighth degree of north and south latitude, is somewhat warmer than the adjacent strata of air. Owing to this decrease of temperature at increasing depths, fishes and other inhabitants of the sea, the nature of whose digestive and respiratory organs fits them for living in deep water, may even, under the tropics, find the low degree of temperature and the coolness of climate characteristic of more

* 'Summer,' by Mudie.

temperate and more northern latitudes. This circumstance, which is analogous to the prevalence of a mild and even cold air on the elevated plains of the torrid zone, exercises a special influence on the migration and geographical distribution of many marine animals." And no doubt it affects the marine vegetation in a corresponding manner, though less striking than the flora of the atmosphere in its zones of altitude.

CHAPTER XIII.

VEGETATION AND CURRENTS OF THE SEA.

General aspect and extent of subaqueous vegetation, § 272.—Great length to which some species of sea-plants grow, 273.—Vast extent of submarine forests in the southern seas, 274.—Geographical range of algæ according to temperature, 275.—Area of the Sargasso Sea in the Atlantic covered with gulf-weed, 276.—Appearance of the Sargasso Sea while sailing through the weed, 277.—Theories as to the origin of so great a mass of vegetation, 278.—Evidence of the Sargasso plant propagating on the surface of the sea, 279.—Hydrographical extent and majestic flow of the Gulf Stream, 280.—Phenomena of the Gulf Stream according to Maury, 281.—Genial effects of the Gulf Stream on the climates of Europe, 282.—Direction of currents ascertained by floating bottles, 283.—Hemispherical division of south and north currents in the sea, 284.—Hypothesis of the universal commingling of sea-water disputed, 285.—Origin of great ocean-currents not satisfactorily explained, 286.—Currents of rotation diverted from their primary course by the upheaval of the land, 287.—In the primeval sea all currents continuous, as in Jupiter, 288.—Equatorial excess of aqueous diameter overlooked by hydrographers, 289.—Convexity of the Gulf Stream an example of the equatorial current, 290.—Binary division of the sea and its currents by the equatorial current, 291.—Black stream of Japan analogous to the Gulf Stream, 292.—Physical phenomena of the two streams compared, 293.—The Humboldt current in the South Pacific Ocean, 294.—Currents of the sea temper the cold and cool the hot regions on land, 295.—Scorched and barren aspect of the shores of the Red Sea, 296.—Abundance of vegetation and animal life in the Red Sea, 297.—Animal life in the Red Sea typical of the world's formation, 298.—Concluding remarks on the hypothesis that the land was first deposited by organic life in the sea, 299.

272. *General Aspect and Extent of Subaqueous Vegetation.*—Of the vegetation that flourishes in the liquid medium of the sea, the numbers of genera and species are few compared with their congeners in the gaseous medium of the air; neverthe-

less they present, as far as we can penetrate to their habitats, equally luxuriant aspects with the groves and forests on shore. Dr Greville—probably the most learned botanist on marine plants—thus epitomises the knowledge derived from many sources on this interesting study:—"We find the vegetation of the ocean no less conspicuous for beauty and variety of form than splendour of colour, admirably fitted for the place it is designed to occupy, and of direct utility to mankind. Viewing these tribes in the most careless way, as a system of subaqueous vegetation, or even in a mere picturesque light, we see the depths of ocean shadowed with submarine groves, often of vast extent, intermixed with meadows, as it were, of the most lively hues; while trunks of the larger species, like the giant trees of the tropics, are loaded with innumerable minute kinds as fine as silk, and delicate as the most transparent membrane. Nor must we forget that while thousands and tens of thousands of quadrupeds, birds, and insects, depend upon the vegetation immediately surrounding us for their very existence, a countless host of creatures derive protection and nourishment from the plants of the deep, appropriated to their use by that merciful Power in whom they live, move, and have their being, whose goodness is over all His works. Some of the algæ, placed, on account of the simplicity of their structure, at the bottom of the scale, are so small as to be invisible to the naked eye, except by the appearance they give to other species on which they happen to be parasitic in prodigious numbers. From these microscopic forms algæ are found of all sizes on our shores, up to thirty or forty feet in length, an extent to which a common sea-weed (*chorda filium*) not unfrequently attains."

273. *Great Length to which some Species of Sea-Plants Grow.*—From the dense medium in which marine plants grow, they are enabled to support their long fronds upon slender stems; and this buoyancy is supplemented in some species by air-vesicles being formed in the fronds themselves. Navigators inform us that their ships have sailed over beds of sea-weed which they estimated by sounding at from 500 to

1500 feet. Perhaps some of the measurements of greatest depth have been incorrect where the sounding-line has been carried away at an angle by some current. In our own voyages we have seen sea-weed on the surface of the water at considerable depths, such as at the entrance to the spacious harbour of Port Phillip in Australia, where the soundings are from 15 to 20 fathoms. The most remarkable thing is, that this sea-plant grows in the channel where an impetuous tide ebbs and flows, calculated, under ordinary circumstances, to uproot the largest trees, yet they bend to the current without breaking their stems, while the long fronds flourish amidst the agitated surf. Taking into consideration the angle at which some of these plants must bend, there are data for concluding that some of them cannot be less than 200 feet from the base of the root to the extremity of the frond.

274. *Vast Extent of Submarine Forests in the Southern Seas.*—Darwin, in his 'Voyage Round the World,' mentions a curious fact regarding a gigantic sea-weed on the shores of South America, near Magellan Strait. "This plant," he says, "grows on every rock from low-water to a great depth, both on the outer coast and within the channel. I believe, during the voyages of the Adventure and the Beagle, not one rock near the surface was discovered which was not buoyed by this floating mud. The good service it thus affords to vessels navigating near this stormy land is evident, and it certainly has saved many a one from being wrecked. I know few things more surprising than to see this plant growing and flourishing amidst those great breakers of the western ocean, which no mass of rock, let it be ever so hard, can long resist. The stem is round, shining, and smooth, and seldom has a diameter of so much as an inch. A few taken together are sufficiently strong to support the weight of the large loose stones to which, in the inland channels, they grow attached; and some of these stones are so heavy that, when drawn to the surface, they can scarcely be lifted into a boat by one person." This sea-plant is the *fucus giganteus* discovered by Captain Cook, who estimated the length of some plants at

not less than 360 feet, although this must be taken as only an approximate measurement. The extent of these beds of sea-weed has been found as marvellous as their height and habitat. "It is found from the extreme southern islets near Cape Horn as far north on the eastern coast as lat. 43°, and on the western it was tolerably abundant, but far from luxuriant at Chiloe in lat. 42°, thus having a range of fifteen degrees of latitude." Rhind, in his work on the 'Vegetable Kingdom,' remarks as follows concerning the wonderful number of living creatures of all orders whose existence depends on these gigantic beds of sea-weed:—"I can only compare these great aquatic forests of the southern hemisphere with the terrestrial ones within the intertropical regions. Yet if the latter should be destroyed in any country, I do not believe nearly so many species of animals would perish as, under similar circumstances, would happen with the kelp. Independent of the numerous zoophytes, amidst the leaves of this plant many species of fish live which nowhere else could find food or shelter. With their destruction the many cormorants, divers, and other fishing-birds, the otters, seals, and porpoises, would soon perish also; and, lastly, the Fuegian savage, the miserable lord of this miserable land, would redouble his cannibal feast, decrease in numbers, and perhaps cease to exist."

275. *Geographical Range of Algæ according to Temperature.*—How the seasons of the sea affect the fructification of marine plants there are but limited data to determine. Botanists class them under the head of *cryptogamia*, where no flower proper is visible. Hence there are no seasons of budding, flowering, and seed-time; so that they exhibit no distinctive character in that respect, as seen in *phanerogamous* or flowering plants. That they have analogous periods of decay and luxuriance with their aerial congeners in temperate regions is beyond doubt, as they "are found upon the British coasts in greatest abundance during the summer months, and in unusual luxuriance during hot seasons. It is probable, also, that sea-plants may be acted on by the temperature of

the water at greater or less depths; and that those species which grow at the bottom of the ocean may have some resemblance to those of the polar circle. On the shores of the British Islands it is easy to perceive that certain species become more plentiful and luxuriant as we travel from north to south; and, on the other hand, that several others occur more frequently, and in a finer state, as we approach the north; while others, again, possess too extended a range to be influenced by any change of temperature between the northern boundary of Scotland and the south-western point of England. The researches and observations of Lamouroux have demonstrated satisfactorily that the great groups of *algæ* do affect particular temperatures or zones of latitude, though some genera may be termed cosmopolite." *

276. *Area of the Sargasso Sea in the Atlantic covered with "Gulf-Weed."*—Could we but observe as closely the fructification, growth, and decay of the plants composing these forests of the ocean as we can the trees and shrubs of our woods, no doubt the observing botanist could discern analogous changes in their structure at certain seasons. At the same time, from the greater equability of ocean temperature throughout the year and through wider ranges of latitude, the seasons in the sea cannot affect submarine vegetation, even in the lowest degree of change, as manifested by plants growing in the air of an evergreen or perennial character. Moreover, in the classification of plants botanists place the *algæ* below the fern tribe and next to the lichens, which, popularly speaking, can scarcely rank as legitimate flowers. In the absence of better information regarding the vast fields of submarine vegetation hid from our sight, we may gather some idea of their extent from the fields of floating sea-weed covering large areas of the ocean's surface. The most extensive tract of this kind is in the Atlantic Ocean, where a species of *algæ* flourishes commonly called "gulf-weed," from the supposition that it is collected by the Gulf Stream, and named *sargassum bacciferum* by botanists, from *sargaço*, the

* Rhind's 'Vegetable Kingdom.'

Spanish for the lentil, which the seeds or air-vesicles of the plant resemble. Hence this region of the Atlantic is designated the *Sargasso Sea* by hydrographers, who consider it an eddy, situated in point of latitude between the regular equinoctial current on the south setting to the westward, the south-easterly current from the northern sea on the east, and as the recipient of the Gulf Stream from the north and northwest. The tract which is occupied is more than twelve hundred miles in length, varying from fifty to one hundred and fifty miles in width, and having a superficies, according to Humboldt, the greater part of which is covered with sea-weed, equal to more than 260,000 square miles. Major Rennel observes that the breadth of this mass of weed is small in proportion to its length, being drawn out into a kind of stream, and bending a little to the east of south. Dr Franklin crossed it in lat. 36°, and found it less than fifty miles wide; but it spreads to the southward, and, in lat. 20° N., appears to be a hundred and fifty miles wide.

277. *Appearance of the Sargasso Sea while sailing through the Weed.*—Though this remarkable collection of sea-weed is situated at a comparatively short distance from the shores of Europe and America, yet it is seldom crossed by mariners, and hence its actual boundaries are not very clearly defined, while the nature of the sea-weed, and the marine creatures living on it, are but little known. Navigators avoid its confines in consequence of the weed impeding the progress of their ships, and in the case of steamers, its collection round the screws and paddle-wheels seriously endangering the machinery. It so happened in our many long voyages, that on rounding Cape Horn and sailing from the South to the North Atlantic, the captain of our ship encountered head-winds as he neared the Sargasso Sea, which compelled him to beat through it for a distance of seven hundred miles before he got into the usual homeward-bound track. Taking advantage of this opportunity to observe the phenomena of this curious sea-weed, so widely spread upon the surface of the ocean, we collected a quantity of it and the

smaller creatures feeding thereon, for examination and preservation. Few of the specimens were more than two feet long, with slender stalks in proportion, covered more or less with the berry-like vesicles, which enabled the whole plant to float on the surface so as to be quite visible to the eye at some distance. When the weather was calm, with little agitation on the water, the sea appeared, in some places where it was unusually dense, like an inundated meadow. Then, when a smart breeze sprang up, and the waves broke in long ridges, the weed collected in rows at distant intervals, having the appearance of hedges partly submerged. If these lay across the ship's course, they very materially impeded its progress; and however much we were pleased to see this famous Sargasso Sea, our captain rejoiced when he sailed out of its latitudes. In looking on this mass of sea-weed in the mid-ocean, we could scarcely divest ourselves of the idea that we were close to the shore though more than a thousand miles from the mainland; while we could easily imagine how the sailors in Columbus's first voyage of discovery hailed its appearance as the indication of land, and, as reported, some leapt overboard expecting to touch the rocks on which it grew.

278. *Theories as to the Origin of so great a mass of Vegetation.*—Various theories have been promulgated as to the origin of this vast "sea-weed meadow." As its common name of gulf-weed denotes, it was supposed by mariners to grow in the Gulf of Mexico, from whence it is carried by the Gulf Stream round Cape Florida, and, proceeding between Bermudas and the Western Islands, settles in the eddy of that vast current which encircles the Atlantic. This hypothesis has not found favour in the eyes of hydrographers, as no uniform current has been discovered capable of carrying the nodules in the direction specified, and to those parts of the ocean where the weed is most abundant. Humboldt was of opinion that it grows on a sandbank raised above the bottom of the sea in form similar to the surface, elongated in shape, and of the area the weed occupies. In support of its

growing at the bottom of the ocean where it is now found on the surface, Mr Luccock remarks :—"It is more than reasonable to suppose, that the plants grow nearly on the spot over which they float : that those which appear on the surface of the water are only the heads or minor branches of others which flourish beneath ; that they are broken off by the agitation of the ocean, or some other accidental circumstance; perhaps by the buoyancy of the air-vesicles themselves, which at a great depth must be fully sufficient for the purpose, as it enables them to float lightly even on the surface of the water." What renders this theory most plausible is the fact, that of the thousands of specimens examined not one has the vestige of a root or fructification as seen in sea-weeds fixed to rocks. But here eminent botanists have come forward to show that some sea-weeds propagate without what are called roots. These Dr Greville considers to be merely holdfasts (*crampons*), and not the organs of absorption as in ordinary plants. Sea-weeds absorb through their whole substance, and the use of their roots is to allow them to grow in favourable circumstances for taking up nourishment. With this and other data connected with fructification, it is now considered that the Sargasso sea-weed may originally have possessed a discoid root, and that, the plant becoming modified in its nature under the peculiar circumstances in which it is placed, it propagates by lateral shoots when floating in the sea. This view of the question seems to us the most probable, as the specimens we examined were most of them bright green at the top as if fresh plucked, while the lower portions were brown and in a state of decay. It would therefore appear as a more likely theory that, as the older parts of the plant decay, they are broken off by the agitation of the waves, and the air-vesicles bursting, these may sink into the depths of the ocean, leaving the floating plants always fresh and green. In that case it is just possible that soundings made in the Sargasso Sea, fishing up specimens of its bed, would show evidence of its vegetable and animal remains, that have been deposited through countless genera-

tions since the remote period when this immense area of the North Atlantic was as clear of sea-weed as other parts are found to be.

279. *Evidence of the Sargasso Plant propagating on the Surface of the Sea.*—Another argument in favour of the Sargasso sea-weed not being merely broken branches from the parent stems growing at the bottom of the Atlantic, where it is probably from two to four miles deep, is the nature of the marine animals found upon it. This point, as far as we are aware, has been overlooked by previous observers, who would lead us to suppose that this vast ocean-prairie—greater than any prairie on the American continent, —was destitute of animal life. On the contrary, there are data for concluding that the surface of the Sargasso Sea swarms with living creatures of every variety found in the ocean, from the microscopic zoophyte to the perfect fish, and all these are more or less dependent on the weed for subsistence. As far as our observations go, there was scarcely a bucket of water taken up, while dipping for specimens of the weed, but contained some tiny pipe-fish, shrimp, or shell; and doubtless more might have been collected, and of larger dimensions, had we possessed better gear for the purpose than simply plunging a ship's bucket over the bows. Now these marine creatures were all of a character that live near the surface of the sea, or, as in the case of the shrimp, on the shallow waters of a sandy shore, and they could not have subsisted at the profound depths of the Atlantic. Hence there is every reason to conclude that the gulf-weed is neither produced on the rocky bottom of the Mexican Gulf, nor on a bank in the mid-ocean, but simply by lateral propagation on the surface where it is found—the boundaries of its distribution being defined by ocean-currents, within which the Sargasso Sea is a vast eddy in the basin of the North Atlantic Ocean.

280. *Hydrographical Extent and Majesty of the Gulf Stream.*—Among the influences of the sea upon the seasons, not merely below but above its surface, none are of more

importance than the great ocean-currents, which have been appropriately designated the "rivers of the sea"—the greatest and most wonderful of which is the Gulf Stream just referred to. Of this phenomenon of the sea, Captain Maury thus writes:—"There is a river in the ocean. In the severest droughts it never fails, and in the mightiest floods it never overflows. Its banks and its bottoms are of cold water, while its current is of warm. The Gulf of Mexico is its fountain, and its mouth is in the arctic seas. It is the Gulf Stream. There is in the world no other such majestic flow of waters. Its current is more rapid than the Mississippi or the Amazon, and its volume more than a thousand times greater. Its waters, as far out from the gulf as the Carolina coasts, are of an indigo blue. They are so distinctly marked that their line of junction with the common sea-water may be traced by the eye. Often one half of the vessel may be perceived floating in Gulf-Stream water, while the other half is in common water of the sea; so sharp is the line, and such the want of affinity between those waters, and such, too, the reluctance, so to speak, on the part of those of the Gulf Stream to mingle with the common water of the sea."

281. *Phenomena of the Gulf Stream according to Maury.*—It is not precisely the province of this part of our subject to enter into details concerning any particular current of the sea, yet we may be excused giving another quotation from Maury's book, describing the extraordinary phenomena of the Gulf Stream. "As to the temperature of the Gulf Stream, there is in a winter's day, off Hatteras, and even as high up as the Grand Banks of Newfoundland in mid-ocean, a difference between its waters and those of the ocean nearly of 20° and even 30°. Water, we know, expands by heat, and here the difference of temperature may more than compensate for the difference of saltness, and leave, therefore, the waters of the Gulf Stream lighter by reason of their warmth. If they be lighter, they should therefore occupy a higher level than those through which they flow. Assuming the depth off Hatteras to be one hundred and fourteen fathoms, and allowing the usual

rates of expansion for sea-water, figures show that the middle or axis of the Gulf Stream there should be nearly two feet higher than the contiguous waters of the Atlantic. Hence the surface of the stream should present a double inclined plane, from which the water would be running down on either side as from the roof of a house. As this runs off at the top, the same weight of colder water runs in at the bottom, and so raises up the cold-water bed of the Gulf Stream, and causes it to become shallower and shallower as it goes north. That the Gulf Stream is therefore roof-shaped, causing the waters on its surface to flow off to either side from the middle, we have not only circumstantial evidence to show, but observations to prove. Navigators, while drifting along with the Gulf Stream, have lowered a boat to try the surface current. In such cases the boat would drift either to the east or to the west, as it happened to be on one side or other of the axis of the stream, while the vessel itself would drift along with the stream in the direction of its course, thus showing the existence of a shallow roof-current from the middle towards either edge, which would carry the boat along, but which, being superficial, does not extend deep enough to affect the drift of the vessel."

282. *Genial Effects of the Gulf Stream on the Climate of Europe.*—This extraordinary current exercises great influence on the climate and seasons in Europe, especially among the British Isles and during winter. "The maximum temperature of the Gulf Stream is 86°, or about 9° above the ocean temperature due to the latitude. Increasing its latitude 10° it loses but 2° of temperature, and after having run three thousand miles to the north, it still preserves, even in winter, the heat of summer. With this temperature it crosses the 40th degree of north latitude, and there overflowing its liquid banks, it spreads itself out for thousands of square leagues over the cold waters around, and covers the ocean with a mantle of warmth that serves so much to mitigate in Europe the rigours of winter. Moving now more slowly, but dispensing its genial influences more freely, it finally meets the

British Islands. By these it is divided—one part going into the polar basin of Spitzbergen, the other entering the Bay of Biscay, but each with a warmth considerably above the ocean temperature. Such an immense volume of heated water cannot fail to carry with it beyond the seas a mild and moist atmosphere. . . . Every west wind that blows crosses the stream on its way to Europe, and carries with it a portion of this heat to temper there the northern winds of winter. It is the influence of this stream upon climate that makes Erin the 'Emerald Isle of the sea,' and that clothes the shores of Albion in evergreen robes; while in the same latitude, on this side (America), the coasts of Labrador are fast bound in fetters of ice."

283. *Direction of Currents ascertained by floating Bottles.*—From the influence of the Gulf-Stream current upon the climate of Europe and navigation of the Atlantic, its course and phenomena have been more thoroughly determined than those of any other ocean-current. But it may be said with truth that the greater part of the sea is more or less subject to currents that render its surface a series of oceanic rivers, continually keeping its waters in circulation. On this point Captain Maury goes so far as to say that they are so mingled with each other "that sea-water from one part of the world is, in the process of time, brought into contact and mixed up with sea-water from all other parts of the world." Without disputing the premises, we would point out that, according to the current-chart of the earth by that eminent hydrographer, there appear to be two great systems of currents, one in the south, the other in the north hemisphere, divided by the great equatorial current, each system independent of the other. From this it is probable that the waters of the two hemispheres do not commingle, each system of warm and cold currents circulating between its equatorial and polar limits. For example: "It is a custom often practised by seafaring people to throw a bottle overboard with a paper, stating the time and place at which it is done. In the absence of other information as to currents, that afforded by these mute little

navigators is of value. They leave no tracks behind them, it is true, and their routes cannot be ascertained. But knowing where they were cast, and seeing where they are found, some idea may be formed as to their course. Straight lines may at least be drawn showing the shortest distance from the beginning to the end of their voyage, with the time elapsed. Admiral Beechey, R.N., has prepared a chart representing, in this way, the tracks of more than one hundred bottles. From it, it appears that the waters from every quarter of the Atlantic tend towards the Gulf of Mexico and its stream. Bottles cast into the sea midway between the Old and the New Worlds—near the coasts of Europe, Africa, and America, at the extreme north or farthest south—have been found either in the West Indies, on the British Isles, or within the well-known range of Gulf-Stream waters. Of two cast out together in south latitude on the coast of Africa, one was found on the island of Trinidad, the other on Guernsey in the English Channel. In the absence of positive information on the subject, the circumstantial evidence that the latter performed the tour of the gulf is almost conclusive. And there is reason to suppose that some of the bottles of the admiral's chart have also performed the tour of the Gulf Stream; then, without being cast ashore, have returned with the drift along the coast of Africa into the intertropical region; thence through the Caribbean Sea, and so on with the Gulf Stream again."

284. *Hemispherical Division of South and North Currents in the Sea.*—In this instance we have a practical illustration of a continuous current circulating within northern latitudes, between 10° and 40°, without crossing the equator into southern latitudes, or even flowing to the north of Europe. If we continue our researches into the South Atlantic Ocean we find currents analogous, in their general circulation, to those in the North Atlantic; and though we have no data to go upon, in all probability a bottle thrown into the main equatorial current south of the line would make the circuit of that ocean along the Brazil coast, crossing over to the Cape

of Good Hope and returning by the South African coast. In like manner the Pacific Ocean has two complete systems of currents in its north and south divisions; while the Indian Ocean, from the greater portion of its waters being in south latitudes, does not show its northern system of currents so clearly defined; yet there is an approximation to the general law involved—namely, that each hemisphere has its own sets of currents more or less independent of the other. At the same time there may be exceptions to the general rule; but these are infinitesimal in proportion to the great law of binary systems of currents in the southern and northern divisions of the sea. And as the general direction of the great currents is longitudinal, we can suppose a drop of water making the circuit of the globe from east to west within a reasonable space of time; whereas the chance of a drop of water in the arctic seas reaching its antipodes in the antarctic circle is a contingency so remote that it appears almost an impossibility.

285. *Hypothesis of the Universal Commingling of Sea-Water disputed.*—Captain Maury assumes that the currents of the sea convey every particle of water over its area and depths, from the uniformity of its constituents wherever analyses have been made. He states:—"If we take a sample of water which shall fairly represent, in the proportion of its constituents, the average water of the Pacific Ocean, and analyse it, and if we do the same by a similar sample from the Atlantic, we shall find the analysis of the one to resemble that of the other as closely as though the two samples had been taken from the same bottle after having been well shaken. How then shall we account for this, unless upon the supposition that sea-water from one part of the world is, in process of time, brought into contact and mixed up with sea-water from all other parts of the world?" We are not prepared to accept this statement of invariable uniformity of analyses of sea-water, for it is well known that the proportion of saline constituents varies considerably—that of the tropical waters of the Atlantic being 1-24th, while in the

German Ocean it is 1-30th. Indeed, if we compare the numerous analyses of the highest chemical authorities, we do not find two agree in the quantities of mineral ingredients; while some have detected the elements of iodine and bromine where others could find no trace. As a rule, therefore, the analysis of sea-water by ordinary chemical means is but a crude approximation to the negative evidence of marine plants and animals, which proves that there are elementary substances in solution that human ingenuity has failed to detect. Of this we have an example in the silicious microscopic shells that prevail in the North Pacific, while in the North Atlantic they are calcareous; from which we infer that silex exists in a greater proportion in the one sea than the other, although no analyst has detected that constituent in a crude form. Taking this into consideration, and looking at the stupendous barrier of the American continent between the two seas, together with their separate systems of currents, we have good evidence that the particles of these oceans do not commingle, as though they were shaken up in a bottle.

286. *Origin of great Ocean-Currents not satisfactorily explained.*—"The existence of ocean-currents has been long known; yet it is only since the later improvements in navigation, especially by the introduction of the chronometer and lunar observations, about the year 1770, that they have been treated as a regular and extensive system; and for this we are chiefly indebted to the valuable researches of Major Rennell. Notwithstanding the many attempts to account for the formation of these great systems of aqueous circulation, the subject is still involved in considerable obscurity. The prevalent opinion is that advanced by Rennell, who supposes that they are produced by the pressure of the trade-winds, and the consequent accumulation of water near the equator. But many examples which he himself adduces prove this opinion to be untenable. For instance, such an accumulation of water could only produce a superficial current; while he shows that many of the stream-currents reach to a very great depth—probably to the bottom of the sea.

Besides, many of the currents have their origin in regions where there are no trade or periodical winds. Among other causes to which they have been attributed by recent authors there are, in addition to trade-winds, the changeableness of atmospheric pressure, the temperature of the air, the difference of temperature or saltness of the sea, the periodical melting of the polar ice, the unequal amount of evaporation at different latitudes, and the local forms of the continents. Humboldt, ascribing their formation to the diurnal rotation of the globe, calls them *currents of rotation.* Doubtless, many of these causes may combine to produce the result; but the laws which govern the motion of fluids in large bodies through each other in currents of different temperatures are not yet sufficiently understood to warrant a satisfactory explanation of these wonderful phenomena. Future investigations will, in all probability, develop a system of marine circulation in perfect harmony with the other ascertained laws of the universe." *

287. *Currents of Rotation diverted from their Primary Course by the Upheaval of the Land.*—In considering this question let us go back to first principles, and we may clear up some points if we do not solve the whole phenomena of currents. We have already referred to that epoch in the history of our planet, when the primeval sea encompassed its nucleus, free from any disturbance of upheaved land. At that period we cannot suppose the existence of the Gulf Stream or similar currents, as it is abundantly evident these were caused by the disposition of the continental masses either disturbing the direction of primary currents or creating a new local circulation of the oceanic waters. On the other hand, we can readily understand that what Humboldt calls *currents of rotation* existed during the earliest periods of the primeval sea, caused by the diurnal rotation of the earth. We can also easily understand that these currents, being unobstructed by any inequality of the ocean-bed, were of great uniformity, flowing round the circumference of the earth in

* Johnston's 'Physical Atlas of Natural Phenomena.'

belts from east to west, as clearly defined as the meridian lines on a globe, diminishing in diameter from the equator to the poles. It requires no stretch of imagination or ingenious argument to prove that, on the upheaval of the land, this uniform system of currents was broken up, and the waters diverted from their primary course to all points of the compass, though still retaining their general direction, as we now find them, especially in the great equatorial current, which maintains its primitive character more than the temperate or polar currents do. Then it followed as a matter of necessity that the minor currents, being hemmed in by the land, assumed new features as they were influenced more or less by the conformation of continents and islands, atmospheric agencies, evaporation, and the other causes enumerated in the foregoing extract.

288. *In the Primeval Sea all Currents continuous, as in Jupiter.*—As to surface currents caused by the action of the wind upon the sea, we have a grand example in those produced by the trade-winds, which are, however, confined in their operations by the land. "Were there a free communication round the globe, at or about its equator, the continuous action of the trades could not fail to establish a westerly circulation of the equatorial waters with little deviation to the north or the south; and were the whole globe covered with water, the compensating south-west and north-west winds beyond the tropics would produce two extra-tropical easterly currents surrounding the globe, and separated from the equatorial one by zones of still water—a lively picture, in short, of what is most probably the state of the planet Jupiter." Thus, if we refer back by induction to the probable condition of the currents in the primeval sea, we will arrive at a more correct view of the principles upon which they are divided into so many different sets, but all obeying the general laws that set them in motion.

289. *Equatorial Excess of Diameter overlooked by Hydrographers.*—It appears to us, however, that a potent influence in regulating the distribution of the currents has been over-

looked. We allude to the diameter of the primeval fluid oblate spheroid at the equator, compared with that between the poles, which was, in all probability, greater than it is now. When astronomers inform us that the equatorial diameter of the globe is some twenty-seven miles greater than its polar, they do not refer to the solid but the liquid area, which is not a fixed quantity, but depends upon the centrifugal movement of rotation. It is a common illustration of this fact to calculate that if the earth stopped in its diurnal revolution, the ocean-currents would rush with tremendous velocity towards the poles in obedience to the law of gravity, so that the two diameters should be equal, and the globe become a perfect sphere at the sea-level. And if such a cataclysm were to occur now, the receding waters would leave the beds of some equatorial seas dry, while they would flood the lands of the polar regions, so that scarcely a mountain would be seen; while all the lower countries of Europe would be submerged, turning the Alps into a group of islands.

290. *Convexity of the Gulf Stream an Example of the Equatorial Current.*—Now, let us consider that this excess of fluid diameter exists on the terraqueous globe at or near the equator in the three great oceans—raising, as it were, a watery mountain between the currents south and north of the line—and we have a solution of the phenomenon of binary systems of currents independent of each other just pointed out. We have quoted Captain Maury's interesting account of "the roof-shaped current" of the Gulf Stream; and in it we have the phenomenon of equatorial expansion exemplified on a small scale. They are both subject to the same oceanic laws. As a farther proof of what has been cited on his authority, of the convexity observable in the Gulf Stream, he states:—"That such is the case is also indicated by the circumstance, that the sea-weed and drift-wood which are found in such large quantities along the outer edge of the Gulf Stream, are rarely, even with the prevalence of easterly winds, found along its inner edge; and for the simple reason that to cross the Gulf Stream, and to pass over from that side to this, they would have to

drift up an inclined plane, as it were—that is, they would have to stem this roof-current until they reached the middle of the stream. We rarely hear of planks or wrecks, or of any floating substance which is cast into the sea on the other side of the Gulf Stream, being found along the coast of the United States. Drift-wood, trees, and seeds from the West India islands are said to have been cast up on the shores of Europe, but never, that I ever heard, on the Atlantic shores of America."

291. *Binary Division of the Sea and its Currents near the Equator.*—If we apply the inferences to be deduced from these facts and phenomena to the equatorial swelling of the sea, though produced by different causes, we can readily understand why the currents in the south hemisphere do not cross the equator and at once commingle with the systems in the north hemisphere, or why drift sea-weed and wreck does not float from the North to the South Atlantic. These would have to ascend an incline, the axis of which is midway across the equatorial current. Hence they are drifted back into the great eddy of the Sargasso Sea, or carried round and round the basin of the Atlantic, or perchance cast up on the shores of Europe, Northern Africa, or North America. It is true that there are under-currents which do not obey the laws that regulate those upon the surface, such as the lower waters of the Gulf Stream, which, according to Maury, when passing through the straits off Cape Hatteras, "are actually forced up an inclined plane whose submarine ascent is not less than ten inches to the mile." But this phenomenon is a purely exceptional one, arising from the Gulf Stream being jammed up in the "narrows" of the Florida Pass, causing the waters to rise, just as those of a great river flowing through a narrow gorge do. It is true also, according to the same authority, that a bottle, thrown from a ship off Cape Horn by an American mariner in 1837, was picked up some eight years afterwards on the coast of Ireland, which Captain Maury considers, "went even from that remote region to the so-called *higher* level of the Gulf Stream reservoir," while it must have

crossed the equatorial current at some place, passing from south to north latitudes. This also may be considered exceptional, as the bottle may have got into some temporary counter-current on the coast of South America, by which it reached Cape St Roque, where the great equatorial current divides—one branch flowing towards the Caribbean Sea, and the other into the South Atlantic. It will be seen that the broad principles we contend for in the distribution of currents over the world are not affected by these exceptions; and that despite them we are entitled to assume the existence of binary systems, each in its own hemisphere and in its own ocean, as distinct and varied as the distribution of islands and continents within the two hemispheres. In the north, as the land predominates, the number of subsidiary currents is greatest; and in the south, where the ocean encircles the globe, they are fewer, but on a greater scale; while the equatorial current keeps more in these latitudes, as if to preserve the vestiges of its primitive uniformity in the primeval sea. Indeed, it may be said that the earth is binary in all its relations—from its own physical structure and phenomena to those of the highest organisms it has produced.

292. *Black Stream of Japan analogous to the Gulf Stream.*—Of the currents in the Pacific Ocean much less is known than of those in the Atlantic; yet the data obtained so far by hydrographers go to prove that this *hemisphere of water*—in the phenomena of its upper and under currents—obeys the general laws in operation, which regulate the whole circulation of waters on the globe. The most interesting fact connected with the Pacific currents is the existence of a warm stream flowing through the north temperate zone in all respects *analogous to the Gulf Stream in the Atlantic*, only upon a smaller scale. And what is deserving of special notice is the circumstance that it tempers the winters of the Japanese Isles in the far East, just as its contemporary does those of the British Isles in the West; while the humidity that arises from it in all seasons has rendered the island of Niphon the "Emerald Isle" of the Pacific. The Japanese being an in-

telligent people, and, like ourselves, experienced in maritime affairs, have observed this peculiar current from the earliest times, noting particularly the darker tint of its waters from those of the adjacent ordinary sea-water. Hence it is named by them *Kuro-Siwo*, which signifies "Black Stream," and it never ceases to run in a north-westerly direction.

293. *Physical Phenomena of the two Streams compared.* — During the American surveying expedition of 1854 in Chinese and Japanese waters, under the command of Commodore Perry, the officers made some particularly interesting observations concerning this current, and its remarkable analogy to the phenomena of the Gulf Stream. These observations were strikingly confirmatory of the views expressed by Captain Maury and others as to the cause of the deflection of the Atlantic Gulf Stream to the eastward, and the cold counter-current below or between it and the shore. There are precisely similar currents, warm and cold, with the same relative position too, on the coast of Japan. "It may be that the first *northward* direction of both currents may be produced by the configuration of the eastern sides of America and Asia respectively; but their turn to the eastward afterwards is probably not influenced by any agency of the land in its shape or position." There are other analogies which the officers observed. A comparison of the temperatures of the two streams showed a striking coincidence. The maximum of 86° Fahrenheit was the same; but in the Kuro-Siwo the difference of 12° between its temperature and that of the ocean proper to the latitude where taken, was somewhat greater than in the Gulf Stream, which averages about 10°, although it reaches 30° in the coldest latitudes. What is still more interesting in these analogies, a sea-weed was found floating within the eddy formed by the Kuro-Siwo, similar in appearance to the gulf-weed, although, from some accident whereby the specimens were lost, it was not determined whether the species was identical with the *Sargassum bacciferum*. At all events, to those on board the squadron, the ships sailed through a portion of the Pacific in all respects similar in

aspect to the Sargasso Sea in the Atlantic. It must be observed here that these two remarkable currents and their attendant phenomena are situated within the north hemi*sphere, and there is no corresponding system of oceanic circulation to be found south of the equator.*

294. *The Humboldt Current in the South Pacific Ocean.*—The southern currents of the Pacific Ocean are but little understood. According to Maury,—"Among those about which most is thought to be known is the Humboldt Current of Peru, which the great and good man whose name it bears was the first to discover. This current is felt as far as the equator, mitigating the rainless climate of Peru as it goes, and making it delightful. The Andes, with their snow-caps, on one side of the narrow Pacific slopes of this intertropical republic, and the current of the antarctic regions on the other, make its climate one of the most remarkable in the world; for, though torrid as to latitude, it is such as to temperature that cloth clothes are seldom felt as oppressive during any time of the year, especially after nightfall."

295. *Currents of the Sea temper the Cold and cool the Hot Regions on Shore.*—Thus do we find the currents of the ocean on one hand cooling the tropical countries along whose shores they sweep, and on the other giving a more genial temperature to climes which would otherwise suffer the severe rigours of winter. Moreover, we find that though the seasons of the sea, in temperate latitudes, cannot compare in their changeable phenomena with those exhibited by the fauna and flora that exist in the atmosphere, yet these are entirely dependent upon the moisture created by the evaporation of the sea, which descends upon the land in the shape of refreshing rain and dew. But for this moisture the land above the surface of the sea would be a barren waste, even where the necessary elements of organic life, heat, and light are abundant. A region of this kind exists on the shores of the Red Sea, which, in itself, is a notable exception to the rule we have pointed out. "That sea lies, for the most part, within a rainless and riverless district—the evaporation from

it is immense; none of the water thus taken up is returned to it either by rivers or rains. It is about one thousand miles long; it lies nearly north and south, and extends from latitude 13° to the parallel of 30° north."* "The lands upon all the shores of the Red Sea are of an arid description; and there flows into no part of it a stream of water that can be called a river, even in the seasons of the rains. The land upon the African side especially is worn to the very bones, and even the rocks, which may be considered the bones of the land, are in a state of decomposition and decay; the very mountains are buried in their own ruins, much in the same way that ancient cities are in many parts of the world—only there comes a month of vegetation over the ordinary ruin; but here there is none. The solid mountain, long since despoiled of its vegetation and its vegetable mould, is now broken like a potsherd, and where the fragments are still too heavy for being blown about by the winds, they drink up every drop of rain, and are both plantless and tenantless." †

296. *Scorched and Barren Aspect of the Shores of the Red Sea.*—We can endorse this description of the barrenness of these shores, having sailed up the Red Sea in our many voyages throughout the world. Having landed at Aden, we there saw an example of the desolation of its shores, though outside its entrance; and as we rode over the crateriform valley where the town is situated, the whole rocky circuit looked like piles of gigantic cinders surrounding a Cyclopæan furnace. Then as we sailed through the strait of Babel-Mandeb, we could appreciate its appropriate Arabic signification of the "Gates of Death." We shall never forget the intense heat and light that prevailed, which approached more to the reality than the figurative expression of a "sea of molten silver." It is called the Red Sea on account of the myriads of infusoria of a blood-red colour seen at times in its waters. When the rays of the sun are reflected therefrom it looks like molten silver, as we have said; and when you look into its depths it is the bluest

* Maury's 'Physical Geography of the Sea.'

† 'Summer,' by Robert Mudie.

of blue seas. But then the arid shores consist chiefly of red rugged rocks and sand, and the red glare of the sky on the African coast gives it a lurid aspect at sunset, which adds to its ancient appellation.

297. *Abundance of Vegetation and Animal Life in the Red Sea.*—"But when we turn from these wasted and worn lands to the sea which washes their coasts, we find not one symptom of desolation or decay. Vegetation in it is like a forest; and perhaps there is no portion of the earth's surface, of the same extent, that supports so many and such varied animals. There are some other circumstances connected with the Red Sea which draw our attention to more extended uses of the world of waters than any which come within the scope of a season, a year, an age, or a period of time as long as that to which human history reaches back. In some parts of that sea countless thousands of *polypi* are constantly at work forming coral reefs, which render the navigation peculiarly dangerous, as a ship may, on a second voyage, be wrecked upon one of those reefs, at the very spot where, on a former voyage a few years previous, or only the preceding year, there was ample depth of water, and not the least vestige of that reef, which now extends for miles, and rises nearly to the surface. Then, in other parts of the same limited sea, volcanic fires are constantly in action, and additional islands and dangers to the navigator are in the course of formation by their means. Along with this there is an activity of vegetable and animal life which is truly wonderful; and there are probably more living creatures in the Red Sea than upon any ten times the same extent of land on the surface of the globe." *

298. *Animal Life in the Red Sea typical of the World's Formation.*—Could we but dive into the depths of this wondrous sea, and explore the recesses of its coral caverns and volcanic rocks, we would see nature's great laboratory in operation, from the elements of which the solid matter of this world was fashioned. Here the countless myriads of infusoria are busily at work secreting from the watery me-

* 'Summer,' by Robert Mudie.

dium the alkalies and earths held in solution to build up their submarine edifices, with fretted roofs and slender pinnacles white as the driven snow. There showers of minute shells are falling down to the bed of the sea, forming deposits of calcareous substance, which the internal volcanic fires consolidate into marble rocks. While here and there some mollusc forms his shell of hues that outvie the colours of the rainbow, which in time decomposes and sinks into the plastic rocks. Everywhere these animated workers are chemically extracting mineral substances from the sea, separating the solids from the fluid matter, to consolidate the crust of the earth on which the sea reposes. Nor is it a mere figure of speech to speak of the "silvery sea;" for, as already shown, it has been proved by circumstantial evidence that the metal itself exists in chemical solution. So may we conjecture that in the primeval sea gold and all the other metals may have formed atoms of its constituent parts, which the busy workers of earlier epochs have exhausted from its store. By pursuing this line of argument, there is no reason to reject the conclusion that in its pristine condition, before any solid matter was extracted from the sea, it contained in solution the elements of every mineral, rock, and metal composing its dense nucleus, as well as that portion we call its crust, of which we have the most knowledge. And it is not unscientific to infer that as the primary molluscs and infusoria utilised the special elements that passed through each alembic, their particular species became extinct as they exhausted those elements, and they were entombed for ever within their own remains.

299. *Concluding Remarks on the Hypothesis that the Land was first deposited by Organic Life in the Sea.*—In expressing our views of organic nature during the earliest epochs of the primeval sea in terms so apparently at variance with received opinions, we may be taxed with allowing imagination to overmaster truth. What, however, is the principle inferred by induction from the premises before us but simply a generalisation of evidence furnished by a multitude of wit-

nesses, that cry out from the depths and shallows of the ocean that they and their progenitors from the creation of our planet have been ceaselessly at work, day and night, from year to year, generation to generation, epoch to epoch, through countless periods of time, laying the solid foundations of the earth? Theorists of the igneous school of cosmogony are too apt to overlook the importance of aqueous formations deposited by marine organisms, and endeavour to class rocks of this character as secondary in the superposition of strata; whereas the evidence is equally strong, if not stronger, that they assisted in the primary work of the world's solid structure, and that the phenomena of volcanic agency were of subsequent origin, metamorphosing the primitive organic deposits, so as to make them appear like purely inorganic formations. These denizens of the profound deep unfold to us a more probable solution of the great geological question regarding the formation of rocks and minerals, than has been hitherto entertained, besides furnishing a sublimer theory of the infancy of our glorious mother earth. Here in the cradle of her childhood we are not introduced to a state of fiery incandescence, blazing in her orbit round the sun, from which she was supposed to be a direct emanation. On the contrary, we see our infant planet cradled in her aqueous sphere, calm and undisturbed, nurturing within her bosom those beautiful living organisms that first laid the foundations of the earth, from whence arose the superstructure of her mountains as she reached the period of her volcanic maturity. Since then the living forces of the sea have attained perfection on the land surrounded by the air, and man has been created as the exponent of her universal vital energy. In contemplating the ocean from this point of view, we behold, not a subsidiary element filling up the hollows of the land for the sake of spherical uniformity, but the vestige of a liquid world, from whence the solid earth was first precipitated, by virtue of that organic chemistry that pervades every drop of water in the ocean. So can we speak of "the heaving of its placid bosom," while sailing over the bound-

less expanse, not merely as a figure of speech, but we can associate with it the knowledge that within its breast the dawn of animal life was nourished. And so also in listening to its murmurs on the pebbly beach, or its loud resoundings along the rocky shore, we hear not alone the concussion of the waves upon the land, but recognise voices uttering a primeval language that tells us, "Earth! O Earth! remember that thou art in all thy living beauty but the offspring of the SEA!"

PART III.

THE AIR

CHAPTER XIV.

THE PRIMEVAL ATMOSPHERE.

Introductory remarks on the vital importance of air in the terrestrial economy, § 300.—Speculative suggestions on extinct geological meteorology, 301.—Hypothesis of a diminution of the vital constituents in the air, 302.—Desolate aspect of a region without air, as observed in the moon, 303.—Description of lunar scenery by M. Guillemin, from the latest observations, 304.—General phenomena of the air according to Dr Buist, 305.—The air a vestige of the earth when in a nebulous state, 306.—Uniformity of winds or currents in the primeval atmosphere, 307.—Cloud-belts in Jupiter typical of the primary belts of the earth, 308.—Calm-zones and currents of rotation in the primeval atmosphere, 309.—Familiar illustration of how the primary air-currents were diverted, 310.—The trade-winds are vestiges of primeval currents of rotation, 311.—Phenomena of the trade-winds according to Ogilvy, 312.—Evidence of intense humidity in the primeval atmosphere, 313.—Phenomena of the great equatorial zone of calms and rains, 314.—This zone of neutral air caused by the opposing currents of the trade-winds, 315.—Commodore Sinclair's account of this sultry and disagreeable region, 316.—Maury's views on the equatorial cloud-ring above the zone of calms and rains, 317.—Torrid zone of winds, calms, and rains, evidence of the climate in Europe during its tropical epoch, 318.

300. *Introductory Remarks on the Vital Importance of Air in the Terrestrial Economy.*—From the study and contemplation of the sea, its wondrous physical phenomena, vegetation, and animal life, we now direct our attention to the AIR, where nature displays still more wonderful aspects of her vitality, and the vicissitudes of the seasons under the genial climates of the temperate zones of the atmosphere, the influences of spring, summer, autumn, and winter, are felt in their highest degree by the vast number of species of the vegetable

and animal kingdoms that depend upon the air for their existence. Without this circumambient medium, which penetrates into every crevice of the land, and rests upon every atom of the sea, all nature on the surface of the earth would be but a lifeless wilderness of desolation. Even if the gaseous elements that compose the atmospheric constituents were different in volume from what they are, so that those which support vitality were diminished or exhausted, few of the innumerable forms that enrich the fauna and flora of the aerial medium would exist. The sun might shed his vivifying rays upon our planet in vain if the vital elements of the air were gone, or so reduced that they failed to support the individuals of the organic world. The sea might still contain vegetation peculiar to itself, and its waters swarm with gill-respiring and other animals united to that denser medium of life. But if the atmosphere were deprived of a comparatively small proportion of oxygen, all air-respiring creatures would cease to breathe. Thus do we find that the most beautiful and the most gigantic forms of animated nature are dependent for their existence upon a certain combination of gaseous atoms of the most subtle character in the atmosphere. It is true that to sustain them it is necessary they should have fluid and solid food according to their organisation, otherwise the more vital elements of the air would fail to support life. These, however, are only modified forms of the vital gaseous elements, which are inseparable from the fountain of life in the air.

301. *Speculative Suggestions on extinct Geological Meteorology.*—A speculative question arises at the outset of our inquiry, whether any changes have occurred in the relative volumes of the atmospheric constituents since the earliest forms of breathing animals appeared upon the earth. If we consider the rapidity of consumption which oxygen undergoes by absorption into the animal frame, and its chemical combination with other bodies by oxidation, we can easily imagine that this gas, as the great vital constituent of the atmosphere, has been subject throughout all time to a process of reduction.

But then we are told that it is evolved by vegetation, and so far its equilibrium may be maintained. This is the point for investigation, which no analyst has satisfactorily determined; consequently we are at liberty to suggest the probable changes that may have occurred in this branch of what we will term *Geological Meteorology*. In the pre-mammalian periods, when enormous lung-respiring reptiles flourished, such as the iguanadon—a lizard measuring from seventy to one hundred feet in length, with a proportionate height and breadth—it is probable that the atmosphere then contained different volumes of its constituents than now, and the change may have been one of the causes that led to the extinction of this and analogous species. In like manner, perhaps, the mammalian monsters of the megatherium, mastodon, and mammoth type may have breathed an atmosphere differing from that breathed by their reptile predecessors as well as at present, and their extinction might have been accelerated by a change in the atmospheric constituents. Besides oxygen, we can imagine a decrease in the constituent of carbonic acid gas, if we consider the immense amount of that constituent which must have been withdrawn during the carboniferous era. So that it is not altogether incompatible with geological evidence that the air has undergone changes equivalent to those of the land and the sea.

302. *Hypothesis of a Diminution of the Vital Constituents in the Air.*—Applying this hypothesis to the present condition of the air as it acts upon the human constitution, we would infer that it does not now contain so large a volume of these vital constituents as it probably did during the earliest ages of man's existence. This we deduce from the prevalence of disease in the human subject, which may be traced, not merely to the presence of malaria in the atmosphere, but also to the liability of contracting disease from a deficiency of vitality in the air itself. Hence it may be that in the course of time, after the human species reaches its maximum increase, it will gradually decrease, and the extinction of mankind be accelerated by a diminution in the volumes of oxygen

and carbonic acid gas in the atmosphere, which do not maintain at present the same healthy equilibrium in the crowded regions of the north hemisphere as is exhibited in the thinly-populated lands of the south. If we could trace correctly the margin between health and disease throughout the earth, in all probability we should find that it lies in a narrow compass, controlled by a small balance in the vital constituents of the air. In like manner there may be only a small reduction necessary to extinguish the great bulk of lung-breathing animals. Thus it may be said that the maintenance of animated beings upon the dry land depends on the volume of oxygen in the air as much as the food raised from the soil. Whether there is a corresponding decrease in the nitrogen gas, which constitutes four-fifths in volume of the atmosphere, there are no data for determining. As long as the sea exists, it is held by meteorologists that the atmosphere cannot diminish in its general volume, which includes the moisture held in suspension. If, however, by some operation of nature, the ocean were to disappear within the crust of the earth, it is supposed that the air, in course of time, would follow it.

303. *Desolate Aspect of a Region without Air, as observed in the Moon.*—That such a condition of natural phenomena is not incompatible with what exists in the universe, is abundantly evident in the physical constitution of the moon, which astronomers have now ascertained, by means of powerful optical instruments—some capable of defining an area or object of 200 yards extent—to be a sphere of the most profound desolation that the human mind can conceive. The views thus furnished are wonderful in their aspect, as if presenting the wreck of a former world now in ruins, and awe-inspiring to the beholder. "If an inhabitant of the earth were transported to the surface of the moon, he would be at once struck with the strangeness of the scene. The configuration of the surface, every corner broken up and rugged—here circular cavities, there elevated peaks; the aspect of the heavens — the bright stars shining in the broad day; the

sharpness of the lights and shades; the eternal silence which reigns in these desolate regions; the extreme temperature, now glacial, now torrid;—all would unite to upset the most familiar notions. Nevertheless, whatever may be the contrasts between the lunar world and our own globe, it will be seen that the variety which is manifested with a marvellous richness here, as in all works of nature, is the effect of but a small number of causes, or rather the result of simple modifications of elements which are really the same for all celestial bodies. The simplicity of the laws which govern astronomical phenomena causes the unity of plan of the whole solar system to shine forth with incomparable clearness."

304. *Description of Lunar Scenery by M. Guillemin, from the latest Observations.*—"We have supposed an inhabitant of the earth landing on the desolate lunar world, bristling with mountains and covered with thousands of volcanic vents. We have described him contemplating with wonder this strange globe. But we ought to mention one fact, which would render his sojourn much more than painful—impossible—namely, that he would not find on the surface of the moon the most indispensable elements of his existence—air and water. The moon, indeed, it would appear, is entirely devoid of atmosphere. This fact seems demonstrated by the occultation of stars. When, by reason of the moon's movement across the constellations, one of the luminous points of the starry vault is covered by the dark part of the lunar disc, it is extinguished suddenly, without any gradual diminution of its light indicating the presence of a gaseous envelope. This fact holds good with the smallest as with the largest stars, even during the eclipses of the moon, when the terrestrial atmosphere is no longer illuminated by our satellite. . . . Is it possible that there may be an atmosphere confined to the bottom of the lowest plains and deepest craters? Nothing renders probable or contradicts this hypothesis. But at all events no cloud ever disturbs the purity of its sky; for clouds, even of slight dimensions, would be easily perceived from the earth. In consequence of this want of atmo-

sphere, the lunar landscapes have a very peculiar aspect—the shadows have everywhere the same blackness. At the most, the crudity of the bright and luminous tints, which stand out on a nearly black sky, is tempered by reflections. Then, again, there is no aerial perspective—none of those effects of light, of those cloud-tints, which give our terrestrial landscapes so much charm and softness. There refraction does not decompose sunshine into glorious colouring and a thousand varied tints; the rainbow and other phenomena of the same kind are unknown on the surface of the moon. No air and no water! This implies, of necessity, absence of winds and currents—absence of motion and sound. For sound, as it cannot be communicated without an aerial medium, can only make itself known by the contact with solid molecules. To an inhabitant of the earth, our light-giver by night would appear, according to the expression of Humboldt, but a silent and voiceless desert." *

305. *General Phenomena of the Air according to Dr Buist.*—Of the atmosphere and its phenomena generally we have a graphic account by Dr Buist of Bombay, in the following extract cited by Maury:—"Its upper surface cannot be nearer to us than fifty, and can scarcely be more remote than five hundred miles. It surrounds us on all sides, yet we see it not; it presses on us with a load of fifteen pounds on every square inch of surface of our bodies, or from seventy to one hundred tons on us in all, yet we do not so much as feel its weight. Softer than the softest down—more impalpable than the finest gossamer—it leaves the cobweb undisturbed, and scarcely stirs the lightest flower that feeds on the dew it supplies; yet it bears the fleets of nations on its wings around the world, and crushes the most refractory substances with its weight. When in motion, its force is sufficient to level the most stately forests and stable buildings with the earth—to raise the waters of the ocean into ridges like mountains, and dash the strongest ships to pieces like toys. It warms and cools by turns the earth and

* 'The Heavens,' by A. Guillemin.

the living creatures that inhabit it. It draws up vapours from the sea and land, retains them dissolved in itself, or suspended in cisterns of clouds, and throws them down again as rain or dew when they are required. It bends the rays of the sun from their path to give us the twilight of evening and of dawn; it disperses and refracts their various tints to beautify the approach and the retreat of the orb of day. But for the atmosphere, sunshine would burst on us and fail us at once, and at once remove us from midnight darkness to the blaze of noon. We should have no twilight to soften and beautify the landscape—no clouds to shade us from the scorching heat; but the bald earth, as it revolved on its axis, would turn its tanned and weakened front to the full and unmitigated rays of the lord of day. It affords the gas which vivifies and warms our frames, and receives into itself that which has been polluted by use and is thrown off as noxious. It feeds the flame of life exactly as it does that of fire—it is in both cases consumed and affords the food of consumption—in both cases it becomes combined with charcoal, which requires it for combustion, and is removed by it when this is over."

306. *The Air a Vestige of the Earth when in a Nebulous State.*—The air has its geological history as well as the sea and land; and if we take into account the relative antiquity of these three divisions of terrestrial matter, the air is the most ancient. We go back to the period when every particle of the earth that is now solid and fluid existed in a gaseous or vaporous form; the atmosphere is the only approximate vestige of its nebulous condition — that condition which astronomers have dicovered to be the state of heavenly bodies in the process of formation in the boundless regions of space. "In the contents of space we see matter either agglomerated into rotating revolving spheres of different density and size, or scattered through space in the form of self-luminous vapour. If we consider first the cosmical vapour dispersed in definite nebulous spots, its state of aggregation will appear constantly to vary. Sometimes appearing

separated into round or elliptical discs, single or in pairs, occasionally connected by a thread of light; whilst at another time these nebula occur in forms of larger dimensions, and are either elongated, or variously branched, or fan-shaped, or appear like well-defined rings, enclosing a dark interior. It is conjectured that these bodies are undergoing variously-developed formative processes, as the cosmical vapour becomes condensed in conformity with the laws of attraction, either round one or more of the nuclei. . . . In comets, which actually constitute the most considerable portion of our solar system with respect to the number of individual forms, the concentrated part, usually termed the *head* or *nucleus*, transmits sidereal light unimpaired. The mass of a comet probably in no case equals the five-thousandth part of that of the earth, so dissimilar are the formative processes manifested in the original, and perhaps still progressive, agglomerations of matter."* Upon this theory of the origin of bodies in space, it has been advanced by Humboldt and other philosophical observers that this world originated from the condensation of aeriform matter. Therefore, as already observed, the air that we breathe, and which appears to be of so evanescent a formation compared with the sea or the land, is more ancient than either, and is to man the most glorious vestige of creation with which he is tangibly acquainted.

307. *Uniformity of Winds or Currents in the Primeval Atmosphere.*—It is not necessary, however, to treat this section of our subject from a cosmical point of view. Our theory of the origin of the seasons will be amply illustrated in its atmospherical phenomena by starting from the same epoch observed at the commencement of the preceding sections, when there was no obliquity of the ecliptic, and the atmosphere rested on an oblate spheroid of water, unbroken by the land. At that period we have assumed that the currents of the sea were simple and uniform compared with their present condition, when they are

* Humboldt's 'Cosmos.'

diverted in all directions by the obstructions of continents and islands. The same remarks apply generally to the primeval atmosphere; only, from its volatile nature, the aerial currents were subject to changes, more or less rapid, caused by solar influences, which affected but slightly the steady currents of the primeval sea. As observed at the present day, there were the two great divisions of currents —one caused by the diurnal revolution of the earth, and the other by the heat of the sun. The former influence may be described generally as producing winds of a permanent character blowing in a longitudinal direction, the latter those of a more evanescent nature blowing in a latitudinal direction. At the epoch, however, to which we refer, these influences combined to produce winds of a steadier kind between the equator and the poles than now exist, chiefly blowing from directions more or less easterly at the equatorial lines—of which we have an example in the north-east and south-east trade-winds—and westerly towards polar latitudes. We can imagine those winds blowing in a perfect zone at that epoch, when no land intervened, and that their influence was felt in much higher latitudes than at present. Indeed, if we take into consideration that part of our theory that the earth revolved upon its axis without any displacement of the equatorial plane from its orbit, it is probable that the primeval winds swept around the globe in belts divided by calm-zones in uninterrupted currents generally parallel with the meridian lines shown upon ordinary maps.

308. *Cloud-Belts in Jupiter typical of the Primary Belts of the Earth.*—Another view may be taken of the winds at this period if we select Jupiter as approximating to the primeval condition of our planet, where apparently the aerial currents of rotation overcome those caused by solar heat, producing those remarkable belts that cross his disc more or less longitudinally. "They are generally parallel to one another, but not always so; and their breadth is likewise variable, one belt having been observed to grow narrow, while another in

its neighbourhood has increased in breadth, as if the one had flowed into the other; and in this case a part of an oblique belt lay between them, as if to form a communication for this purpose. The time of their continuance is very uncertain—sometimes they remain unchanged for three months, at other times new belts have been formed in an hour or two. In some of these belts large black spots have appeared, which moved swiftly over the disc from east to west, and returned in a short time to the same place; whence the rotation of this planet about its axis has been determined. . . . The time of rotation, according to Cassini, Miraldi, and others, is 9 hours and between 55 and 56 minutes. . . . The changes in the appearance of the spots, and the difference in the time of their rotation, make it probable that they do not adhere to Jupiter, but are clouds transported by the winds, with different velocities. . . . The radius of Jupiter being nearly 11 times (10.86) that of our earth, and his rotation being 2.4 times more rapid, it follows that the space passed over by a point on his equator is 26 times greater than that passed over by a point of the terrestrial equator in the same time. Hence the centrifugal force is 26 times greater."* From this tremendous velocity in its axial rotation, and the dense clouds arising from an oblate spheroid in all probability presenting nothing but water on its surface, it has been concluded by astronomers that the belts of Jupiter are caused by the currents of its atmosphere.

309. *Calm-Zones and Currents of Rotation in the Primeval Atmosphere.*—In this planet we have an example of what the earth was at the period under review, only we have no data to determine whether its bulk and velocity of diurnal revolution approached that of Jupiter, or even if these were greater than they are at present. Calculating by the universal law of aggregation, according to Humboldt, observable in the formation of planetary bodies, always from a lighter medium of extended dimensions to a denser nucleus of smaller circumference, we should infer that the bulk of the world was

* Art. "Astronomy," 'Encyclopædia Britannica.'

then larger than at present, and the atmosphere of greater extent and humidity; while probably the velocity of the diurnal revolution was more rapid. But it is not necessary to speculate upon what may have been the physical condition of the earth at this period as affecting atmospheric phenomena, for we have ample evidence that there were not only belts of winds and clouds, but zones of calms that divided the circulation of the air into separate systems of currents. Captain Maury has constructed a diagram of the winds, which gives an excellent idea of these belts of calms and winds, showing four of the latter divided by three of the former, besides two discs of polar calms. Looking at this diagram, we see at once how the belts of Jupiter are formed; and we can easily suppose that a sentient being possessed of telescopic power in any of the other planets would observe similar belts around the earth—which we may consider existed in the primeval atmosphere, before the zones were broken up by the upheaval of the land, more perfect than they now are.

310. *Familiar Illustration of how the Primary Air-Currents were diverted.*—It requires no great amount of scientific knowledge to understand how the primeval currents of air were subsequently diverted from their course at certain localities by the interposition of islands and continents. The inhabitant of any large city may see the principle in operation on a windy day, where the true direction of the breeze aloft is scarcely to be found among the streets and squares below. For example, take London, and observe its level site. Here, before a house was built, the west wind swept across the native heath in a straight line towards the east. Now that same wind will blow down one street as from the north-west, and from the south-west in another, according to the angle in which it is built, while it will eddy round St Paul's at all points of the compass. If we magnify these structures of man to the dimensions of the continental works of nature, we can see how a great belt of wind blowing from west to east may become a different wind along the

shores of a continent, or among the Alps may twist and turn in all directions. It is not, however, the purport of our researches in the regions of atmospheric phenomena to enter into the minutiæ of aerial currents, but generally to inquire how far they assist in mingling the atoms of the atmosphere; and, on the other hand, how far the belts of calms prevent the commingling of the air at the opposite latitudes of the south and north temperate zones, if not the two hemispheres.

311. *The Trade-Winds are Vestiges of Primeval Currents of Rotation.*—Regarding the constant winds or currents of the atmosphere, we are informed by Captain Maury that "from the parallel of about 30° north and south, nearly to the equator, we have, extending entirely round the earth, two zones of perpetual winds—viz., the zone of north-east trades on this side, and of south-east on that. With slight interruptions they blow perpetually, and are as steady and as constant as the currents of the Mississippi river, always moving in the same direction, except when they are turned aside by a desert here and there to blow as monsoons, or as land and sea breezes. As these two main currents of air are constantly flowing from the poles to the equator, we are safe in assuming that the air which they keep in motion must return by some channel to the place toward the poles whence it came in order to supply the trade-winds. If this were not so, these winds would soon exhaust the polar regions of atmosphere, and pile it up about the equator, and then cease to blow for the want of air to make wind of. This return-current, therefore, must be in the upper regions of the atmosphere, at least until it passes over those parallels between which the trade-winds are always blowing on the surface. The return-current must also move in the direction opposite to that wind the place of which it is intended to supply. These direct and counter currents are also made to move in a sort of spiral or loxodromic curve, turning to the west as they go from the poles to the equator, and in the opposite direction as they move from the equator toward the poles.

This turning is caused by the rotation of the earth on its axis. The earth, we know, moves from west to east. Now, if we imagine a particle of atmosphere at the north pole, where it is at rest, to be put in motion in a straight line toward the equator, we can easily see how this particle of air, coming from the very axis of diurnal rotation, where it did not partake of the diurnal motion of the earth, would, in consequence of its *vis inertiæ*, find, as it travels south, the earth slipping from under it, as it were; and thus it would appear to be coming from the north-east and going toward the south-west—in other words, it would be a north-east wind. On the other hand, we can perceive how a particle of atmosphere that starts from the equator to take the place of the other at the pole, would, as it travels north, in consequence of its *vis inertiæ*, be going towards the east faster than the earth. It would therefore appear to be blowing from the south-west and going towards the north-east, and exactly in the opposite direction to the other. Writing south for north, the same takes place between the south pole and the equator."

312. *Phenomena of the Trade-Winds according to Ogilvy.*—A less technical yet lucid description of the trade-winds is concisely given in Blackie's 'Imperial Dictionary,' as follows:—"The trade-winds are those perpetual or constant winds which occur in all open seas on both sides of the equator, and to the distance of about 30° north and south of it. They are so named because they are favourable to navigation and trade. On the north of the equator their direction is from the north-east (varying at times a point or two of the compass either way); on the south of the equator they proceed from the south-east. The origin of the trade-winds is this: The great heat of the torrid zone rarefies and makes lighter the air of that region, and in consequence of this rarefaction the air rises and ascends into the higher regions of the atmosphere. To supply its place, colder air from the northern and southern regions rushes towards the equator, which also, becoming rarefied, ascends in its turn. The

heated air which thus ascends into the upper regions of the atmosphere, being there condensed, flows northward and southward to supply the deficiency caused by the under-currents blowing towards the equator. These under-currents, coming from the north and south, are, in consequence of the earth's rotation on its axis, deflected from their course as they approach the equatorial region, and thus become north-east and south-east winds, constituting the trade-winds."

313. *Evidence of intense Humidity in the primeval Atmosphere.*—It is important to note here that a space of atmosphere intervenes between these two contending winds, "extending at different seasons from about 150 to 500 miles. Here the two winds meet, with opposing forces so nearly balanced as to neutralise each other and produce a calm." * This is the tract of air so much dreaded by mariners in their voyages from the North to the South Atlantic, where the navigation is subject to sudden and violent storms of thunder, lightning, and rain, accompanied by heavy squalls of wind, which as suddenly cease, when a dead calm prevails in the sultry humid air, more oppressive than the storm of rain. "When the north-east and south-east trade-winds meet and produce the equatorial calms, the air, by the time it reaches this calm-belt, is heavily laden with moisture; for in each hemisphere it has travelled obliquely over a large space of the ocean. It has no room for escape but in the upward direction. It expands as it ascends, and becomes cooler; a portion of its vapour is thus condensed, and comes down in the shape of rain. Therefore it is that under these calms we have a region of constant precipitation. Old sailors tell us of such dead calms of long continuance here, of such heavy and constant rains, that they have scooped up fresh water from the surface of the sea." † Thus, when the sea was universal, the humidity of the primeval atmosphere would be intensely greater than at present.

314. *Phenomena of the great Equatorial Zone of Calms*

* Johnston's 'Physical Atlas.'
† Maury's 'Physical Geography of the Sea.'

and Rains.—These permanent winds, with the dividing zone of calms and variable winds, extend across the Atlantic and the greater width of the Pacific, but they are not so well defined in the Indian Ocean, where the continent of Asia affects the north-east trade-winds so as to convert them into monsoon winds, blowing one-half the year in that direction, and the other half from the south-west. So also on the continent of Africa these winds and calms are not defined as on the sea, in consequence of the great breadth of land within its tropical latitudes. The same causes affect the south-east trade-winds, where the widest portion of the South American continent extends its shores; but the north-east are less affected where the Atlantic and Pacific trade-winds are only separated by the comparatively narrow region of Central America; while the belt of calms is almost united when, at certain seasons, it reaches the Isthmus of Panama. From this it will be inferred that the equatorial zone of calms is not stationary, and likewise the trade-winds which produce it. They follow the sun in his apparent annual course from the Tropic of Cancer to the Tropic of Capricorn, and *vice versâ.* At the same time there is considerable inequality in the two sets of winds. The south-east trade-winds form a wider belt than the north-east, and their force is greater. Consequently they press them back at times as far as the 9th degree of north latitude, and rarely allow them to enter southern latitudes. "It is a remarkable phenomenon that the annual movements of the trades and calm-belts from south to north, and back again, do not directly follow the sun in its declination, but appear to wait until the temperature of the sea-water puts it in motion. The trades and the belt of calms do not decline before the temperature of 80° of the water in the North Ocean turns it southward; and in the spring they do not go northward until the temperature of 80° returns." * •

315. *This Zone of neutral Air caused by the opposing Currents of the Trade-Winds.*—Now this belt of calms, according to the best authorities, is considered as a damming-up

* Lieutenant Jansen, cited by Maury.

of the atmosphere between the two great aerial currents. Hence it has been found, by barometrical observations, to measure a column of air less dense than those of the winds on either side, but of intense humidity. So that it is like a reservoir into which the trade-winds discharge their surplus air and moisture, until a barrier, as it were, of neutral atmosphere has become collected, separating their currents almost as effectually as the Gulf Stream divides the ordinary sea-water. As the winds approach its confines they take an upward course, producing what sailors term a "lifting-wind," when the sails of the vessel swell out like balloons, and actually lift the ship fractionally out of the water. Well do we remember the delightful motion created thereby when bounding through the north-east trade-winds over a gentle sea, which realised all our previous notions of what the poet describes as "sailing on the wings of the wind." And well do we recollect, also, the discomfort and wearisomeness of being becalmed in the "doldrums," as the sailors quaintly term the variable winds and calms of this tropical belt of the atmosphere. It was, therefore, with enhanced pleasure that we again entered the trade-wind at the opposite boundary of the calm-zone into southern latitudes, where the buoyancy and brightness of the air are even more exhilarating than to the north of the equator. The passage through this belt is the theme of all voyagers from the North to the South Atlantic; and recently their name has been legion, as all emigrant ships from Europe to the golden lands of Australia have to cross it.

316. *Commodore Sinclair's Account of this sultry and disagreeable Region.*—Of the many accounts given, few surpass the following graphic sketch by Commodore Sinclair of the United States navy, as cited by Maury:—"This is certainly one of the most unpleasant regions in our globe. A dense, close atmosphere, except for a few hours after a thunder-storm, during which time torrents of rain fall, when the air becomes a little refreshed; but a hot glowing sun soon heats it again, and but for our awnings and the little air put

in circulation by the continual flapping of the ship's sails, it would be almost insufferable. No person who has not crossed this region can form an adequate idea of its unpleasant effects. You feel a degree of lassitude unconquerable, which not even the sea-bathing, which everywhere else proves so salutary and renovating, can dispel. Except when in actual danger of shipwreck, I never spent twelve more disagreeable days in the professional part of my life than in these calm latitudes. I crossed the line on the 17th of January at eight A.M., in longitude 21° 20′, and soon found that I had surmounted all the difficulties consequent to that event; that the breeze continued to freshen and draw round to the south-south-east, bringing with it a clear sky and most heavenly temperature, renovating and refreshing beyond description. Nothing was now to be seen but cheerful countenances, exchanged as by enchantment from that sleepy sluggishness which had borne us all down for the last two weeks."

317. *Maury's Views on the Equatorial Cloud-Ring above the Zone of Calms and Rains.*—The intelligent reader will readily suppose that, in a region of such heavy and constant rains, there must be dense clouds continually hovering about, of that kind named *nimbus* by meteorologists, or the well-known rain-cloud. So dense and constant are these in the zone of calms separating the trade-winds, that Captain Maury appropriately designates it the "Equatorial Cloud-Ring." "Ceaseless precipitation," he says, "goes on under this cloud-ring. Evaporation under it is suspended almost entirely. We know that the trade-winds encircle the earth; that they blow perpetually; that they come from the north and the south and meet each other near the equator; therefore we infer that this line of meeting extends around the world. By the rainy seasons of the torrid zone, except where it may be broken by the continents, we can trace the declination of this cloud-ring, stretched like a girdle round our planet, up and down the earth—it travels up and down the ocean, as from north to south and back. It is broader than the belt of calms out of which it rises. As the air, with its

vapours, rises up in this calm-belt and ascends, these vapours are condensed into clouds, and this condensation is followed by a turgid intumescence, which causes the clouds to overflow the calm-belt, as it were, both to the north and south. The air, flowing off in the same direction, assumes the character of winds that form the upper currents that are counter to the trade-winds. These currents carry the clouds still further to the north and south, and thus make the cloud-ring broader; at least we infer such to be the case, for the rains are found to extend out into the trade-winds, and often to a considerable distance both to the north and south of the calm-belt." In his enthusiastic observations regarding the phenomena of the cloud-ring, Captain Maury compares it to the rings of Saturn, which it would resemble, only more rugged in its outer rim, to an inhabitant of that planet if the earth's cloud-ring were luminous. With all due deference to his opinion, we should compare it more appropriately to the dark belts of Jupiter, or those on the body of Saturn.

318. *Torrid Zone of Winds, Calms, and Rains evidence of the Climate in Europe during its Tropical Epoch.*— If we apply this observed phenomenon of intense humidity with belts of constant winds and calms within the present tropics to our theory of an extended torrid zone in the primary atmosphere, we have a solution of the question of atmospheric moisture that prevailed in Europe during its tropical epoch. Comparing the fossil remains of vegetation at that period with what exist at present, we find the extinct flora of the British Isles analogous to that of the West Indies, where the islands revel in luxuriant succulent plants. These indicate a moisture and heat in the air during the greater part of the year of which we have no experience at the present day, even scarcely in the hottest days of summer. Instead of the comparatively dry atmosphere and cool sea-breezes that blow through our forests of oak and pine, invigorating the robust frame of the peasant, the air was charged with humidity, and intensely hot both by night and day;

while jungles of rank vegetation sprang up among the palm-tree forests, generating malaria from the marshy ground. During the transition periods between that epoch and the present era of the seasons, there were changes in the currents and condition of the air which altered, modified, and broke up the uniformity of the primeval atmosphere.

CHAPTER XV.

CIRCULATION AND CONSTITUENTS OF THE AIR.

Theory of independent circulation in the tropical air-currents, § 319.—The equatorial belt of calms acts as a barrier between the trade-winds, 320.—Momentum of probable atmospheric waves, 321.—Tropical calm-belts acting as barriers between the north and south temperate winds, 322.—The question arises whether the air commingles north and south, 323.—Maury's theory in favour of universal intermingling of the atmosphere, 324.—How particles of air are supposed to circulate from pole to pole, 325.—Principle of Maury's theory inconsistent with atmospheric phenomena, 326.—Maury's arguments why air must possess the same constituents in both hemispheres, 327.—Theory of a disparity in the volume of constituents of air in the temperate zones, 328.—Maury's remarks on propounding a new hypothesis, 329.—Our own views on the importance of studying the phenomena of the air, 330.—Dr Priestley first discovers that air is a compound body, 331.—Mr Cavendish anhlyses the volumes of its constituents, oxygen and azote, 332.—Foreign chemists confirm Cavendish's experiments, 333.—Carbonic acid gas discovered as an element in the air, 334.—No analysis of the atmosphere made in the south hemisphere, 335.—Scientific observers at the Cape and in Tasmania overlooked analysis of the air, 336.—Numerous observatories in Australia, but none analysed the air, 337.—Surveying expeditions in southern oceans made no analysis, 338.—Inquiry as to existence of negative evidence showing disparity of volume in the constituents of the air, 339.

319. *Theory of independent Circulation in the Tropical Air-Currents.*—Among the phenomena of winds and calms that characterise the distribution of the great aerial currents, the question that bears most directly on the theory broached in this essay is that which relates to their hemispherical division. As we have seen in the foregoing part on "The Sea" that there appears to be a binary separation of the oceanic currents north and south of the equator, so in the atmosphere

there is a belt of equatorial calms that divides the winds caused by the earth's rotation on its axis. Hence we have to consider a series of winds and calms between the poles that occur in duplicate, like the meridian lines on a globe, apparently independent of each other, and separated at the equator. Without endorsing the entire theory of Maury relating to the phenomena of the equatorial zone of calms and rains, we agree with his lucid demonstration of the general character of this zone, which has been described by numerous other meteorologists—namely, that there is a counter-current in the upper regions of the atmosphere blowing in a contrary direction to that of the trade-winds on either side of the equator. We have already observed that this zone of comparatively neutral air, varying in width at different seasons and different meridians on the ocean from 6° to 9° of latitude, was the receiver of the surplus humidity of the trade-winds blowing into it. But it does not follow that the gaseous atoms of azote, oxygen, and carbonic gas are also absorbed into it; for, large as this aerial receptacle is, it would not contain a tenth part of the trade-winds. The more correct deduction to be drawn from the data given would be, that the air, having discharged the moisture absorbed in its passage over the "wide waste of waters" in those latitudes where the trade-winds blow into the calm-zone, the pure air ascends above the region of precipitation, and returns to those higher latitudes from whence it sprang in a highly-purified condition within the Tropics of Cancer and Capricorn. Here the upper return-currents, meeting with two other calm-belts, into which they have no moisture to discharge, enter the lower currents as comparatively dry winds. Thus the circulation of this tropical section of the atmosphere is kept up within limits as clearly defined as the great equatorial currents of the ocean. To illustrate this view of aerial circulation more clearly, it is necessary to refer to the annexed diagram, exhibiting an imaginary vertical section of the atmosphere.

320. *The Equatorial Belt of Calms acts as a Barrier*

between the Trade-Winds.—An important question arises here, whether the pure air on the north side of the equatorial belt of calms and rains ever commingles in its constituent elements with that on the south side. If we accept the foregoing theory in its entirety, we cannot see how this

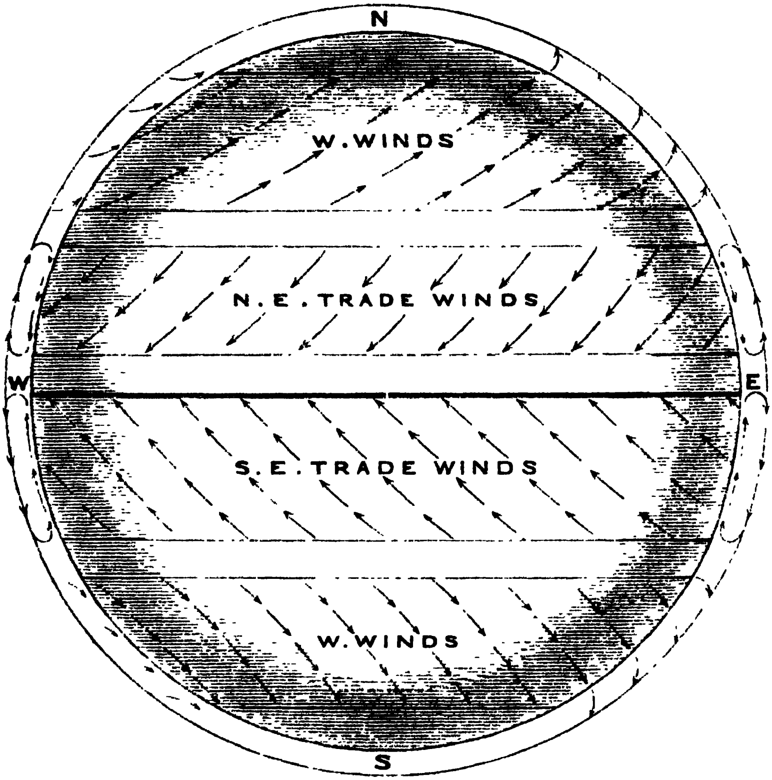


Fig. 11.

Showing the Equatorial and Tropical Calm-Zones, the Trade-Winds, and prevailing westerly winds in the North and South Hemispheres, with a new theory of Atmospheric Circulation.

can take place, with such a humid barrier of neutral air between. It is true that the particles of water held in suspension by the two currents of air mingle together, and form the rain-clouds that produce this great hyetographic zone. It is also probable that portions of each lower current mingle with

the neutral air, and become at rest for a time until they ascend into the upper regions and mingle with the counter-currents. But it does not appear how an immense bulk of air like the north-east trade-winds, blowing with considerable strength, being suddenly checked by a neutral zone of atmosphere, saturated with moisture, can cross that barrier and commingle with the south-east trade-winds. According to the law of forces, the particles of air would rebound from this concussion of a moving current against a comparative stationary body of air. And as we have seen that the trade-winds have an upward tendency in their course towards the equatorial belt of calms, there is no doubt but that the upper return-current is assisted greatly by the rebound of the particles of air from their momentum.

321. *Momentum of probable Atmospheric Waves.*—Moreover, we deem it a question not yet satisfactorily determined, whether there is not a momentum in the atmosphere independent of its moving atoms—that is, a force of wind produced without the particles of air moving with the same velocity—just as we find in the motion of a wave, where there is no corresponding movement in the atoms of water. According to meteorologists, it appears to be a foregone conclusion that all winds are *currents of air*, where the particles move along like the flow of a river, or, what is more apposite, the motion of the Gulf Stream in mid-ocean. No doubt such is the basis of all winds of long continuance or permanence, as the tropical trade-winds and constant temperate westerly winds. But it is well known that these winds impart an impetus to the particles of the ocean that form waves, which travel with great velocity and beat with vast power on the solid land, without any actual current of water beyond the rolling of the surf upon the beach. May not the atmosphere, which furnishes the impelling power in this instance, acquire a similar momentum, and the actual *force* of a wind be greater than the current of air or its velocity? As there are forces in the waves of the sea independent of oceanic currents, may not there be atmospheric waves imparting force to the particles of air in

addition to ordinary currents? This may be a nice question to solve as regards the trade-winds, but it is different with reference to the sudden gusts of wind which blow with terrific violence in the belt of calms. Although the lowering of the barometer indicates the approach of violent squalls, yet they are so sudden, so strong in pressure of wind, and so short in duration, that the theory of air-currents is not sufficient, in our opinion, to account for the phenomenon. As the question is one that bears upon the general subject of the universal intermingling of the atmospheric atoms, we point it out as a possible element in our theory which supports a hypothesis to the contrary.

322. *Tropical Calm-Belts acting as Barriers between the North and South Temperate Winds.*—Besides this equatorial belt of calms, we have shown in the diagram the calms of Cancer in the north hemisphere, and a corresponding zone in the south under the Tropic of Capricorn. The average width of these calm-belts is calculated variously—sometimes less and sometimes wider than the equatorial belt of calms. They separate the winds of the temperate zone from the trade-winds; and in this respect act as a barrier to their commingling, just as the equatorial belt does between the trades. In these calm regions it has been ascertained that the pressure of air is lower than it is to the north or the south of them, which has been instanced as a proof that the atmosphere is rarefied into an ascending current by the neutralising influences of the trade-winds on one side being easterly, and the temperate winds, which blow in an opposite direction. Within the influence of the latter winds there are regions of constant rain, but not so heavy as that of the equatorial belt of calms. These calms of the tropical limits are likewise subject to the solar influence, moving north and south according to the declination of the sun. In this movement they mark what are termed periodical rains, or those that occur in certain tropical latitudes at fixed periods of the year, which are succeeded by dry seasons of equal duration more or less.

323. *The Question arises whether the Air commingles North*

and South.—Here we have a second and a third belt of neutral air surrounding the earth—one in each hemisphere—that evidently must affect the commingling of the atmosphere generally, again raising the question whether such commingling really takes place. On this point Captain Maury expresses himself as follows :—"Arrived with my investigations at this stage in the construction of a theory, a question of this sort arose: Does the air which is poured into those calm-belts from the north, for instance, return to the north as it flows out, or does it keep on its circuit towards the south?" In endeavouring to solve this important problem, which is one of vital interest to mankind as well as science, Captain Maury adheres to his hypothesis, that in the atmosphere, as in the sea, every particle of air and water not only changes its position in the circumference of the globe, but that there is a continual change of atoms between the poles; so that, in the course of time, the entire ocean is shaken up, even to its profoundest depths, as effectually as if it "were shaken in a bottle," to use his own expression. In the previous division of our subject on "The Sea," we have ventured to dissent from this doctrine of universal circulation; for, however beautiful it may be in theory, as an instance of the harmony of all moving things in the universe, there are data for concluding that the currents of the ocean do not mingle universally, as explained in that section. In like manner, with a consistency we cannot but admire, however we may dissent from his hypothesis, the gallant physical geographer of the sea endeavours to show, by an ingenious mode of argument, that the atmospheric atoms cross the three belts of calms in their circulation from the north to the south pole, and *vice versâ*, as regularly as the particles of air forming the trade-winds circulate within their own domain. In elucidating his theory of universal polar circulation, he has constructed a "Diagram of the Winds," with a marginal reference to the course supposed to be pursued by two imaginary particles of air—one starting from the north pole and the other from the south. The course of each at starting is in the upper current of air, presumed

to exist at the poles, until they reach the tropical calm-belts, when they descend and *cross each other* in the still medium, each pursuing its latitudinal course, ascending and descending alternately, until all the three belts are crossed, and the north pole particle reaches the south pole, where it rests in a supposed *disc* of polar calms, until it ascends and again returns to the north polar *disc* of calms—and so on *ad infinitum.* In order, however, to do justice to the author of this hypothesis, we must again briefly quote his own words :—

324. *Maury's Theory in favour of universal intermingling of the Atmosphere.*—"The earth, we know, moves from west to east. Now, if we imagine a particle of atmosphere at the north pole, where it is at rest, to be put in motion in a straight line toward the equator, we can easily see how this particle of air, coming from the very axis of diurnal rotation, where it did not partake of the diurnal motion of the earth, would, in consequence of its *vis inertiæ*, find, as it travels south, the earth slipping from under it, as it were ; and thus it would appear to be coming from the north-east and going toward the south-west—in other words, it would be a north-east wind. . . . Setting off from the polar regions, this particle of air, for some reason which does not appear to have been satisfactorily explained by philosophers, instead of travelling on the surface all the way from the pole to the equator, travels in the upper regions of the atmosphere until it gets near the parallel of 30° north. Here it meets also, in the clouds, the hypothetical particle that is coming from the south and going north to take its place. About this parallel of 30° north, then, these particles press against each other with the whole amount of their motive power, and produce a calm and an accumulation of atmosphere ; this accumulation is sufficient to balance the pressure of the two winds from the north and south."

325. *How Particles of Air are supposed to circulate from Pole to Pole.*—"Following our imaginary particle of air from the north across this calm-belt of Cancer, we now feel it

moving on the surface of the earth as the north-east trade-wind; and as such it continues till it arrives near the equator, where it meets a like hypothetical particle, which, starting from the south at the same time the other started from the north pole, has blown as the south-east trade-wind. Here, at this equatorial place of meeting, there is another conflict of winds and another calm region; for a north-east and south-east wind cannot blow at the same time in the same place. The two particles have been put in motion by the same power, they meet with equal force, and therefore, at their place of meeting, are stopped in their course. Here, therefore, there is a calm-belt. Warmed now by the heat of the sun, and pressed on each side by the whole force of the north-east and south-east trades, these two hypothetical particles, taken as the type of the whole, cease to move onward, and ascend. This operation is the reverse of that which took place at the meeting near the parallel of 30°. This imaginary particle then, having ascended to the upper regions of the atmosphere again, travels there counter to the south-east trades, until it meets, near the calm-belt of Capricorn, another particle from the south pole: here there is a descent as before; it then flows on to the south pole as a surface-wind from the north-west. Entering the polar regions obliquely, it is pressed upon by similar particles flowing in oblique currents across every meridian; and here again is a calm place or node; for, as our imaginary particle approaches the parallels near the polar calms more and more obliquely, it, with all the rest, is whirled about the pole in a continued circular gale. Finally, reaching the vortex or the calm place, it is carried upward to the regions of the atmosphere above, whence it commences again its circuit to the north as an upper current, as far as the calm-belt of Capricorn: here it encounters its fellow from the north; they stop, descend, and flow out as surface-currents, the one with which the imagination is travelling to the equatorial calm, as the south-east trade-wind; here it ascends, travelling thence to the calm-belt of Cancer, as an upper current counter to the north-east

trades. Here it ceases to be an upper current, but, descending, travels on with the south-west passage winds toward the pole."

326. *Principle of Maury's Theory inconsistent with Atmospheric Phenomena.*—Our first impression of this ingenious hypothesis is its intricacy. In nautical phraseology these imaginary particles of air, in pursuing their course from pole to pole, have found it a *very intricate piece of navigation;* and it has been only by the skilfulness of their pilot that they have reached their destination in safety. Seriously, however, even the talented propounder of this hypothesis will admit that it is a complex theory, and one where the imagination has more to do than perception in following the line of argument. In some respects it is inconsistent with Captain Maury's views regarding the laws of other physical phenomena. For instance, there is no blending of the atmosphere, as he says of the sea, so that it also should be everywhere mingled, or, as it were, "shaken up in a bottle." Apparently the particles of air retain their particular current, and cross each other at the calm-belts, as if they were of distinct constituent parts—the one like oil, the other like water, so that they crossed each other without combination. This we consider a point that requires more conclusive arguments than those given to support it. It is just possible that a small percentage of the great aerial currents north and south of the equator may *slip through*, as it were, from one side of the calm-belt to the other; but that the immense body of air in each system of winds maintains a kind of cross-firing in the upper regions of the equatorial calm-zone, is too much to entertain for a scientific hypothesis. Moreover, according to this theory, the atmospheric currents produced by the law of gravitation and the rotation of the earth on its axis would appear to be subsidiary to some polar influence, gratuitously supposed to give momentum to the particles of air forming this imaginary system of currents,—which is contrary to experience, and even data furnished elsewhere by Maury himself.

327. *Maury's Arguments why the Air must be the same in the North and South Hemispheres.*—Evidently Captain Maury was not satisfied with his first sketch of this novel hypothesis, for he discusses the question more practically in an additional chapter to the later edition of his work on the 'Physical Geography of the Sea.' Without entering further into these fresh arguments than as they are contained in the first paragraph, we shall examine the question from a point of view differing entirely from that adopted by him, yet shadowed forth in the following quotation:—"There seem to be reasons for supposing that the air which enters the calm-belts from the north flows out toward the south, and *vice versâ*; consequently, it was held that the construction of the atmospherical machinery is such as to require a crossing air in those calm-belts. . . . The identity of atmospherical constituents in all parts of the earth, notwithstanding the unequal distribution over its surface, both as to place, numbers, and kind of the agents which corrupt and of those which purify the air,—this identity of constituents seemed to favour the idea of a general and regular intermingling—nay, the principles of adjustment which obtain in that exquisite system of compensations which is displayed in the workings of the physical machinery of our planet seem to call for such regular and active intermingling of the fluid covering, both aerial and aqueous, of the earth, as would keep each element pure and make it homogeneous. Were it not so, we know of physical agents which, in process of time, would make both the air and the water of the two hemispheres quite different those of the one from those of the other. Consequently, if the atmosphere of one hemisphere were to become different from that of the other, the air of the north would not be suited to the flora and fauna of the southern hemisphere, and conversely."

328. *Theory of a disparity in the Constituents of the Air in the Tropical Zones.*—Now, in adopting this first postulate as datum for his hypothesis, Maury has assumed as a foregone conclusion that the constituents of pure air—nitrogen, oxygen,

and carbonic acid gas—are in equal proportions throughout the entire atmosphere and over every part of the earth. To this we take exception, inasmuch as the atmosphere has not been chemically analysed in regions remote from Europe to determine this point; and, as far as our researches have gone, we cannot find a scientific analysis of the atmosphere in the south hemisphere, such analyses being all confined to regions north of the equator. Moreover, in support of this conclusion, he infers that the fauna and flora of both hemispheres live under the same atmospheric conditions, otherwise the air of the one would not suit the animals and plants of the other if transported thither. This last deduction does not follow; for the air of one hemisphere might improve the physical condition of the fauna and flora of another; as, for example, were these transported from the north temperate regions to corresponding parallels in south latitude. On these points we shall produce data from scientific sources and personal observation in the south hemisphere, tending to prove that "the identity of atmospherical constituents in all parts of the earth" is not absolute, as Maury and meteorologists generally lead us to believe; and that there is evidence to show that the constituents of the south aerial hemisphere do not universally commingle with those of the north.

329. *Maury's Remarks on propounding a new Hypothesis.*—In venturing to submit these personal observations and other data in support of a theory opposed to the opinion of the world in general, and endorsed by high authorities on the question, such as Captain Maury, it is with no dogmatic intention that we bring them forward. On the contrary, it is with a sincere desire to add, if possible, to the sum of human knowledge in the grand study of physical geography—with a view to improve the physical and moral condition of mankind—that we submit to abler minds the result of our observations on the atmosphere in the most remote regions of the earth during a long course of experience on land and sea. It is just possible that, among the data to be furnished in support of our views, some missing link in the chain of

evidence may be found to complete even the existing theory as propounded by Maury. In that case we shall be satisfied with the result in the propagation of scientific discovery, although different from our preconceived opinions, if the new data given support a truthful hypothesis. It is in this spirit that Maury conducted his labours while compiling his admirable work on the 'Physical Geography of the Sea,' wherein he expresses himself in the following manner upon this point:—"Whenever, in the course of my investigations touching the physics of sea and air, new facts have been elicited, I have, if they appeared consistent enough to be suggestive, never hesitated to follow them up with suggestions, especially if hypothesis seemed to be called for. The principle by which I have sought to be governed is this: fairly to weigh the facts under discussion, and then offer in explanation that hypothesis which would apparently best reconcile them. In case I could not reconcile all by any one supposition, the preference has been given to that hypothesis which would reconcile the greatest number. Then, as additional facts were developed, the hypothesis was, if necessary, discarded or amended, as the new lights seemed to require. As an investigator in the particular field to which much of my labour is directed, I do not consider that I should content myself by merely stating observations and facts. It is the business of the investigator to let those who labour with him have the benefits of his thoughts and conclusions, as well as a fair statement of his facts. Such thoughts, though they be founded in misapprehension, rarely fail to help the course of progress and of truth; for, though wrong in themselves, they impart interest to the subject, set others to thinking, and often suggest what is right. Moreover, by such a course discussion is encouraged; and scientific discussion, when philosophically directed and properly conducted, is always profitable."

330. *Our own Views on the importance of studying the Phenomena of the Air.*—To the general reader these minute investigations into the constituent elements and circulation

of the atmosphere may appear superfluous, as enough is already known for all the uses of mankind. We would remark to such persons that, irrespective of its high scientific results, nothing can be of greater advantage to the community generally than a true knowledge of that medium on which not only the health but the life of every human being depends. It frequently happens in our experiences of and researches into the physical world, that those objects and phenomena most familiar to our senses are the least understood, and we are better acquainted with the nature of those at a distance. This arises, in a great measure, from the popular notion that things around us are common and understood by everybody; while things at a distance are new to us, and require to be investigated on account of their novelty. Such is the general impression abroad on the phenomena of the atmosphere; and persons of ordinary intelligence would feel themselves offended if they were asked what was its composition, and how it affected their constitution. Yet these are points that remain undetermined even at the present day, in an era when scientific investigation has become one of the most advanced studies in our universities; and it is to be hoped that ere long in the humblest school a better knowledge of the air we breathe will be taught to the poorest scholar.

331. *Dr Priestley discovers that Air is a compound body.* —A century has not elapsed since Dr Priestley (1774), a famous English chemical analyst, first demonstrated that air was a compound body, and not the simple element which the ancients thought it to be, and from which, in their opinion, all things originated. He was the discoverer of oxygen gas, and showed it to be a constituent of air. "He determined several of its most remarkable properties, and called it *dephlogisticated air*, from a notion that it was air deprived of *phlogiston*. When *azotic* gas, the other constituent of air, was discovered soon after, the difference between its properties and those of oxygen gas could not fail to strike the most careless observer. Bodies burn more

rapidly, with much greater splendour, and with the evolution of much greater heat, in oxygen gas than they do in common air; while in azotic gas they cannot be made to burn at all. Animals breathe oxygen gas without inconvenience, and they live much longer when confined in a given bulk of it, than when in the same volume of common air; but in azotic gas animals cannot live at all. When plunged into it they die of suffocation, precisely as they would do if plunged into water."*

332. *Mr Cavendish determines the proportions of Oxygen and Azote.*—About the same time a Swedish *savant* named Scheele made a similar discovery that the air consisted of two elementary gases, without having any knowledge of what had been done in Britain; and he further determined their relative proportions—assigning, in 100 parts of air, 27 volumes of oxygen gas and 73 of azote, or, as it is now termed, nitrogen gas, from being the radical of nitric acid. In France, Lavoisier the great chemist drew the same conclusions as Scheele, without knowing what had been done by his Swedish contemporary. Both, however, were in error, and it was reserved for Mr Cavendish of London to determine more exactly the volume of each constituent. "It was in 1782 that Mr Cavendish, by a careful analysis of the air in the neighbourhood of London, repeated frequently, and continued for a whole year, determined that the volume of oxygen gas in 100 volumes of atmospherical air is 20.82, and of nitrogen 79.18." A spirited discussion amongst the most eminent scientific men in Europe followed, upon the gaseous elements of the air, among whom were Dr Ingenhousz of Vienna and others, who advanced the proposition "that air differs in the proportion of oxygen gas which it contains in different parts of the earth, and that the salubrity of different places is connected with this difference." "The experiments of Mr Cavendish were published in the 'Philosophical Transactions' for 1783; but they continued for many years unattended to. The determination of Scheele and Lavoisier

* Art. "Atmosphere," 'Encyclopædia Britannica.'

was universally adopted; and the notion of Dr Ingenhousz, that the proportions between the oxygen and the azote vary in different places, was adopted."* This opinion, however, was subsequently discarded on finding the proportions of oxygen within a fraction the same everywhere, whether the air was taken from a salubrious or unhealthy locality. Had these analytical experiments been carried into the south hemisphere, probably this notion of the Viennese doctor would have been found to be correct on a more extended scale, though not in limited areas, or under local influences.

333. *Foreign Chemists confirm Cavendish's Experiments.*—This question of relative volume remained undetermined until 1802, when "Berthollet announced that he had frequently analysed the air in Egypt by absorbing its oxygen by means of a stick of phosphorus, and that he always found it a compound of 79 volumes azote and 21 volumes oxygen. . . . Davy, about the same time, announced that he had tried air from the coast of Africa, from Cornwall, and from the neighbourhood of Bristol, and had uniformly found it composed of 79 volumes of azotic gas and 21 volumes of oxygen gas. It was soon after analysed in Edinburgh, in North America, and in France with the very same results. Gay-Lussac and Humboldt made a set of careful experiments to determine the exact proportions of the two constituents, and confirmed the ratio of 21 volumes of oxygen gas and 79 volumes of azotic gas. This ratio has been generally adopted by chemists."

334. *Carbonic Acid Gas discovered as an Element in the Air.*—"Besides oxygen and azotic gases, air likewise contains a little carbonic acid gas. Who first made that remark we do not know; but it was an almost inevitable inference, as soon as the cause of the difference between caustic and mild alkali became known. Chemists at first stated the volume of carbonic acid gas in the atmosphere at 1 per cent, but this determination was not founded on any accurate experiment. Mr Dalton found the quantity much smaller than had been

* Art. "Atmosphere," 'Encyclopædia Britannica.'

stated by preceding experimentalists. . . . But by far the most complete set of experiments on the volume of carbonic acid gas in the atmosphere was made by M. Saussure. . . . The experiments were continued for two years. Sometimes (indeed most commonly) the air examined was collected at Chambeisy, a meadow about three-fourths of a league from Geneva, elevated about 52½ feet above the lake, and distant from it 820 feet. The mean quantity of carbonic acid gas found in 10,000 volumes of air, deduced from 104 observations made during both day and night, was 415 volumes. The greatest quantity was 574 volumes, and the smallest 313. . . . If we admit the mean volume of carbonic acid gas in air to be 0.000415, then the true component parts of 100 volumes of air will be *

Azotic gas, ...	79.9668	100"
Oxygen gas, ...	19.9917	
Carbonic acid gas, ...	0.0415	

335. *No Analysis of the Air made in the South Hemisphere.*—In estimating the value of this determinate analysis of the atmospherical constituents, it will be observed that all the chemical experiments relate to the air in the north hemisphere, and that they are chiefly confined to that in Europe. It is true that some were conducted in Egypt, the African shores of the Mediterranean, and the east coast of North America, but we do not learn of any having been made in the far East—in China, for example, where it is just possible that some variation might be found. In like manner no carefully-conducted chemical analysis of the atmosphere has been made in the south hemisphere, as far as we know. At this we need not be surprised, as the regions south of the equator occupied by European nations at the time these atmospherical investigations were going on, had not made sufficient progress in civilisation to invite learned *savans* from their laboratories at home, for an unsafe residence among anarchical communities in the settlements of South America

* Art. "Atmosphere," 'Encyclopædia Britannica.'

and South Africa, or those of felons in Australia, and savages in New Zealand. Indeed, it may be said that it is only within the last seventeen years or so that the scientific world, aided by the English and colonial governments, and in a small degree by some other European governments, has begun to investigate more particularly the physical phenomena of the south hemisphere, in consequence of the valuable gold discoveries made in the British possessions of Australia and New Zealand.

336. *Scientific Observers at the Cape and in Tasmania overlooked Analysis of the Air.*—The only instances that occur to us of scientific investigations being conducted on land in the south hemisphere that might have led to a careful analysis of the air, previous to the era in question, were at the Cape of Good Hope and in the Island of Tasmania. At the former colony Sir John Herschel had established an observatory for astronomical purposes, in connection with Greenwich observatory—not only to make observations on the constellations of the south celestial hemisphere, but to profit by the remarkable purity and clearness of the atmosphere there, in observing the nebulae, the galaxy, and other cosmical phenomena. It does not appear that this eminent astronomer availed himself, during a residence of many years at the Cape, of the opportunity of analysing the brilliant atmosphere around him. Evidently he rested satisfied with the analyses in northern regions, and confined his observations to the special astronomical mission upon which he was sent. In like manner an observatory was established for some years at Hobart Town, Tasmania, by the Government Hydrographic Department, to ascertain the nature and direction of electric currents, and the force and duration of magnetic storms in that locality, as indicative of the magnetic forces generally in the south hemisphere. But the commission appointed to carry out these investigations, although registering thermometrical and barometrical observations, together with other atmospherical phenomena, paid no scientific attention to the chemical analysis of the air, being content,

apparently, with that ascertained in the north as applicable to the south hemisphere.

337. *Numerous Observatories in Australia, but no Analysis of the Air.*—Since the gold discoveries in Australia, observatories have been established in the principal cities of each colony that will compare with the smaller establishments of the kind in Europe for the method in which the observations are conducted. Not only is this the case at Melbourne, in the colony of Victoria, but "for many years past the colonial government has maintained a system of meteorological stations in various parts of the colony, of which the Melbourne observatory forms a centre; and regular observations of temperature, pressure of air, humidity, radiation, rain, &c., have been obtained for longer or shorter intervals at each. These stations are distributed so that nearly all districts possessing any climatic peculiarity are represented, with the exception, perhaps, of the higher altitudes in the mountain-districts, and the arid plains in the north-west." Besides these facilities for observing atmospherical phenomena—as enumerated in the report of the local government astronomer—Victoria was fixed on by the late King of Bavaria as a region for scientific inquiry in the south hemisphere. Accordingly he commissioned a learned *savant*, named Professor Neumeyer, to proceed to Melbourne with a complete set of the most improved magnetic, meteorological, and astronomical instruments, in order to make a series of observations on magnetic and atmospheric phenomena. On his arrival the local government allowed him the use of a public building on an eligible site, and the legislature of the colony very liberally voted an annual allowance towards the maintenance of the establishment during his stay. Although this learned professor applied himself diligently to his task for three years, during which he added materially to our knowledge of Australian meteorology, yet in all his reports no reference is made to the constituents of the atmosphere in that region. The same may be said of the annual reports from the observatories in the other southern colonies. However minute the

tables issued by their conductors may be in registering the monthly and annual temperature, humidity, pressure of air, rainfalls, winds, and clouds, no reference whatever is made to the greater or less proportion of nitrogen, oxygen, and carbon in the atmosphere.

338. *Surveying Expeditions in Southern Oceans make no Analysis.*—Although not to be placed in the same category with land observations, yet, notwithstanding the numerous surveying expeditions in the south hemisphere accompanied by men of science, and the many times the southern waters of the globe have been circumnavigated, no allusion has ever been made, as far as we know, to the gaseous elements of the air these ships have passed through in the scientific observations taken during their voyages. From all these, and other examples that might be cited, it would appear that scientific men, as well as the world at large, are satisfied with the investigations and results of the analysts at the close of the past and the commencement of the present century—that the air is universally the same in its elementary constituents, from its circulation intermingling all its atoms in a series of winds or currents, so that in every meridian and parallel from pole to pole it forms one vast aerial sphere of chemical unity consisting of nitrogen gas, 79.9668 parts; oxygen gas, 19.9917 parts; and carbonic acid gas, 0.0415 parts.

339. *Inquiry as to negative Data showing disparity of Aerial Constituents.*—We shall now proceed to inquire what data, if any, exist to show that these proportions may be different in the south from the north aerial hemisphere. At the outset it must be premised that we do not intend to produce *positive* data towards supporting such a hypothesis; for if we had counter-chemical analyses to those already quoted, the matter would simply rest upon the authenticity of the experiments and the competency of the experimentalists. Having no evidence of this kind to produce as direct proof of a disparity in the two hemispherical divisions of the atmosphere, we may with logical propriety have recourse to *negative* data in elucidation of the theory. This is no new or

weak mode of investigation, and many important discoveries in the physical world have been made through observing the effects of an unknown cause, which has been subsequently proved to exist upon substantial grounds. It is just possible, therefore, that however apparently feeble may be the arguments and evidence we bring forward in support of this theory, they may lead some competent experimentalist to analyse the air in the south hemisphere; and the result of his experiments may prove the correctness of our views.

CHAPTER XVI.

DIFFERENCE BETWEEN THE VEGETATION OF THE NORTH AND SOUTH HEMISPHERES.

Diminution of carbonic acid gas in the north aerial hemisphere, § 340.—The air highly charged with the carbonic element during the carboniferous era, 341.—Carbon extracted from the air buried in the coal-measures, 342.—Numerous species of fossil ferns in the carboniferous formation, 343.—Carboniferous fossil trees different from existing forest-trees in Europe, 344.—Trees and shrubs of New Zealand analogous to the extinct flora of Great Britain, 345.—General aspect of New Zealand forest scenery and vegetation, 346.—Peculiar surface-roots of the trees in New Zealand, 347.—Extraordinary roots and trunk of the Rata-tree, 348.—New Zealand trees derive all their carbon from the atmosphere, 349.—Vegetation of New Zealand typical of the carboniferous flora of Europe, 350.—Magnificence of the tree-fern forests of New Zealand, 351. Arborescent ferns derive their strength from air and moisture, 352.—Greater volume of the carbonic constituent in the south aerial hemisphere, 353. Tropical division of Australia, and its humidity, 354.—Aridity of the temperate regions of Australia, 355.—An Australian sirocco blows during summer in Victoria, 356.—A hot wind at Melbourne described, 357.—Forests and pastures on fire during the hot winds in Victoria, 358.—Open and monotonous aspect of the forest-scenery in Australia, 359.—Australian gum-trees the highest trees in the world, 360.—Dr Mueller's account of the Australian jungle, 361.—Rapidity of growth in Australian gum-trees and acacias, 362.—Evidences of a large volume of the carbonic constituent in the atmosphere of Australia, 363.—Evergreen characteristics of all the vegetation in the south hemisphere, 364.

340. *Diminution of Carbonic Acid Gas in the North Aerial Hemisphere.*—Throughout the preceding sections of this work the intelligent reader may have observed that the line of argument adopted has been from the lesser to the greater series

of facts and postulates — sometimes from the infinitesimal to the infinite. For example, in building up our theory of the origin of the seasons, through infinite periods of time and the transcendent operations of nature on the earth, we approached the superstructure of our argument through the comparatively trifling and neglected phenomenon observed by astronomers in the diminution of the obliquity of the ecliptic. Following a similar line of investigation into the vast circumambient medium that enfolds the world in its embrace, and endeavouring to unravel the history of the primeval atmosphere, we shall select the comparatively infinitesimal constituent of carbon in its elementary form as a key to open this temple of hidden knowledge. Although a mere fraction of a fraction of an element in the grand atmospheric compound compared with its two great fellow-constituents, nitrogen and oxygen, there is abundant evidence to prove that at one period carbonic acid gas entered largely into the component parts of both the air and the sea—as the universality of mineral carbonates fully testifies. Without referring more particularly to the oceanic part of the question, we shall quote again the illustrious Humboldt's opinion on this point in treating of the internal reaction of the earth on its surface during the upheaval of mountains and mineral masses:—"The influence of this reaction of the interior on the exterior is not," he thinks, "limited to inorganic nature alone. It is highly probable that in an earlier world more powerful emanations of carbonic acid gas, blended with the atmosphere, must have increased the assimilation of carbon in vegetables, and that an inexhaustible supply of combustible matter (lignites and carboniferous formations) must have been thus buried in the upper strata of the earth by the revolutions attending the destruction of vast tracts of forest." Hence it has been concluded, after taking into consideration the immense extent of the carboniferous and lignite formations which have not returned their elements into the atmosphere by combustion, that the volume of carbonic acid gas in the north aerial hemisphere now, is probably only

that the abundance of vegetation at that period in Europe surpassed anything that we know of in the world at present, not excepting the dense forests and jungles of the tropics. Not only has the preservative power of carbon handed down the remains of these fern-forests and club-moss marshes, but in the imperishable impressions of their fronds in shale, limestone, and sandstone, botanists have classified some two hundred and fifty species of ferns alone in the British Isles, while in all Europe at the present day there are not more than fifty species. Moreover, as the fern tribe is peculiarly exempt from the decay produced in most plants by immersion in water, so do its members flourish most luxuriantly in a humid atmosphere and a rainy climate, especially in rocky situations, where the spray of waterfalls sprinkles their fronds unceasingly. Hence it has been concluded that heavy and constant rains must have fallen on the newly-upheaved lands at this epoch; but it does not follow that extreme heat prevailed, for in those regions at the present day where ferns attain their greatest luxuriance, the temperature is moderate.

344. *Carboniferous Fossil Trees different from existing Forest-Trees in Europe.*—The question that suggests itself here is, How far the vegetation that formed the coal-fields depended upon the atmosphere for its supply of carbonic acid gas? If we are to suppose that the peat-bogs, dense forests, and jungles of that period presented an aspect similar to the bogs, woods, and thickets of Europe at the present day—where the trees send their tap-roots deep into the soil, with their numerous rootlets spread out underground, extracting their carbon from the earth and water, in which it mingles largely—we should conclude that only a small proportion was absorbed from the air. But it must be remembered that the ground on which these primeval forests grew had not been long upheaved above the ocean, and there could be little or no soil formed on the bare volcanic rocks to convey nourishment or moisture through their roots. Moreover, the roots could not penetrate the hard rocks, so that they

must have been spread out on the surface; and as there were many trees of gigantic growth at that period, these could not have tap-roots, but depended for their fixity on the ground upon their general spread over it. In that case the roots would approach in character those of a sea-weed, which we have seen is a mere holdfast or *crampon*. Then, being of a highly carboniferous nature, they must have absorbed the element which nourished their woody fibre from the primeval atmosphere, which learned chemists and botanists inform us, as we have seen, upon experimental data, must have been highly charged with carbonic acid gas.

345. *Trees and Shrubs of New Zealand analogous to the extinct Flora of Great Britain.*—But we may be told that these characteristics of the trees and shrubs forming the ancient carboniferous forests of the British Isles, of which the coal-fields are the remains, are become imaginary, as they are not supported by the prevailing features of the trees and shrubs in our living forests. These evidently absorb but a very small portion of their carbon from the air, as their leaves are not adapted for that purpose, while the foliage is stripped from their branches during one half the year, with nothing exposed to the air but hard stems, which cannot so effectually perform the office of absorption. On the other hand, the roots of most European trees penetrate to a great depth, spreading out in their ramifications, almost equal in extent to the upper branches, and seldom appearing on the surface. We must not look, however, for evidence to support our views among existing forests in Europe, but to those in remote parts of the world exhibiting a living vegetation analogous to the extinct flora of the carboniferous era. As a field for illustrating this remarkable phenomenon of the primeval atmosphere and its vegetation, no region is so interesting and characteristic as the New Zealand group of islands, situated nearly at the antipodes of the British Isles. In consequence of that position and their geographical area, and being a dependency of this country colonised by the British, that colony has been appropriately termed the "Great Britain

of the South." The interest, therefore, attached to the botanical and physical features becomes still more appropriate, if we can see in them an existing type of our mother-country when it first "arose from out the azure main." Having travelled through a great part of the interior of New Zealand, we can vouch for the peculiar character of its flora, indicated in the foregoing remarks as resembling the extinct vegetation of the carboniferous era in Europe. And we shall endeavour to show that with the resemblance between the existing flora of that south region, and the extinct flora of its northern antipodes, there are also data for concluding that the air of the south hemisphere at present is probably as highly charged with carbonic acid gas as that of the primeval atmosphere was in Europe.

346. *General Aspect of New Zealand Forest Scenery and Vegetation.*—New Zealand forests, as a rule, are remarkably well defined from the adjacent open lands, where a tree or a clump of bushes is rarely seen rising from amongst the fern-brake which covers the ground in the absence of indigenous pasture. So clear is the line of demarcation, that at first sight we supposed that it was the work of the native inhabitants; but on closer examination we could see that it was the handiwork of nature from some peculiarity of the rock on which the trees and shrubs grew being more favourable to the growth of dense masses of vegetation than where it was open, or, as in some places, nearly barren. Be that as it may, our first observations on entering one of these forests were the definite boundary outside, with the contrast between the dingy fern-brake and the magnificence of the trees and underwood inside. And as we penetrated its recesses we were equally struck with the remarkable network of roots that covered the surface of the ground, rendering walking along the native path very fatiguing, as we had to spring from root to root to avoid stepping into the pools of water everywhere collected between them. Although it was not raining at the time, or had done so that day, yet the moisture that hung upon the foliage was so dense that it continued dropping

down, amid the profound silence of the forest, like the heavy drops of rain before a thunder-shower. It was a fine warm day, with the sunlight shining through the maze of vegetation, yet we soon got wet from the falling moisture; at the same time it was not the steamy humidity of a tropical forest, for the atmosphere was clear enough to see any distance, where the prospect was not intercepted by the dense foliage. Altogether its general aspect was that of exceeding freshness, and even sparkling, where the globules of moisture glittered like gems in the sunbeams of a bright New Zealand day.

347. *Peculiar Surface-Roots of the Trees in New Zealand.*—Besides the network of roots incommoding the road, there were so many climbing-plants on each side that it was not an easy matter to diverge from the path without using a tomahawk to cut through those in our way. Having done this, we reached a comparatively clear spot to survey the characteristics of a New Zealand forest. Everywhere that the ground was visible between the roots, its rocky character became apparent; and at a precipitous part the trees seemed perched on rocks, which their roots entwined like the claws of some gigantic bird, allied to the extinct *dinornis* or *moa* of the Maories. The trees towered up to a great height—many with their trunks free of branches for eighty or ninety feet, and from six to eight feet diameter at the base, above where the roots begin to branch off upon the surface of the ground. It was curious to see where these twisted around in all directions, the roots of one tree intertwining with those of another, like groups of vegetable snakes, making up for the remarkable absence of any such reptile on these islands. At one spot where a monarch of the forest had been blown down by the wind, the disc of roots stood up twenty feet high, leaving the rock bare below, showing how little this giant tree depended upon the soil for nourishment, if indeed it received any at all. The knotted roots of these large trees furnish highly-ornamental wood, which equals in beauty the bird's-eye maple. On the other hand, the leaves are ever-

green and succulent, through which the moisture and gaseous elements are absorbed. For example, the Rimu (*Dacrydium cupressimum*). This beautiful tree comes to its greatest perfection in shaded woods. Its foliage is remarkably graceful and elegant. The leaves are only small prickles, running up a long stem, from which, towards the top, branch out several other stems, whose united weight causes the main stem to hang like the branches of the weeping willow, or a cluster of ostrich feathers; and the beauty is heightened by the liveliness of the colour with which it is decorated, in comparison with the sombre hue of most of the other evergreens.

348. *Extraordinary Roots and Trunk of the Rata-Tree.*—To enumerate the variety and characteristics of the trees to be found in the forests of New Zealand is beyond the limits of our subject; yet we may appropriately point out one or two species presenting the remarkable features of their vegetation. Of these the rata (*Metrosideros robusta*) is perhaps the most peculiar, as representing a plant of enormous dimensions, almost independent of nourishment from the soil, like some orchidaceous epiphytes that subsist upon the gases and moisture of the air while hanging from the branches of trees. The characteristic variety of this tree grows at first as a parasite, creeping in numerous stems, like ropes, up the trunks of the other forest-trees, gradually enclosing them till they perish, and then uniting to form a noble tree taller than that which it has destroyed, with an enormous trunk, but hollow within. Those trees sometimes attain a hundred feet in height, with the base of the hollow trunk eight or nine feet in diameter. To support this mass of timber, the snake-like roots spread over the ground in a circular form, measuring sometimes a hundred and fifty feet in its outer circumference. These are smooth and covered with bark, like the trunk and branches, so that it is impossible to say where the roots begin and the stem ends. The leaf and the flower resemble those of the myrtle, but the flower is of a deep-crimson colour, with yellow stamens. In December and January these giants of the forest give the hill-sides a

fairy-like appearance, from the profusion of their beautiful blossoms. The branches are gnarled like those of the oak, and the trunk also, from its formation, is a series of strange contortions, so that the wood, being also heavy, close grained, and very durable, is most valuable to the shipbuilder for knees and timbers of all shapes and sizes.

319. *New Zealand Trees derive all their Carbon from the Atmosphere.*—Here, then, we have a timber tree of massive woody tissues, derived chiefly from carbonic acid gas—at least its carbon basis is so derived; and it requires no profound knowledge of botany or chemistry to see, by the structure of the plant above the surface of the ground, that this all-important element is extracted from the atmosphere. Yet it is maintained by eminent botanists and experimental chemists that all the carbon composing the woody fibre of plants is derived from the soil. The only question is how that is absorbed, as it is well known that charcoal, the crude state of this element, is not soluble in water, therefore it cannot enter the minute vessels for circulation in plants. On the other hand, M. Senebier, a learned vegetable physiologist, has endeavoured to prove that carbonic acid gas, dissolved in water, supplies the roots of plants with almost all their carbon. We incline to the latter theory, and bring forward the peculiar character of the surface-roots of trees in the New Zealand forests in its support. We have described how, on entering these woods, we had to leap from root to root in order to avoid the little puddles of water collected between them. Now we can easily understand in a wet climate, such as exists there, that these collections of rain-water rarely dry up, and are constantly extracting carbonic acid gas from the air, which the surface-roots are continually absorbing; so that water and moisture are the mediums through which the great mass of vegetation in New Zealand derives nourishment from the gaseous elements in the atmosphere. This argument, however, does not disprove the theory that trees with underground roots in the north hemisphere derive their carbonic acid gas from the soil, where it is evolved from manures, and

combines with the rain or river water that percolates through the ground.

350. *Vegetation of New Zealand typical of Carboniferous Flora of Europe.*—Although flowers are few and far between in these New Zealand forests, yet there is remarkable beauty in the scenery among the undergrowth of vegetation, produced by the fronds of the great variety and abundance of ferns, surpassing even the most picturesque foliage of deciduous shrubs and flowers. If, as it has been remarked by the eminent botanists already quoted, we have in these far southern islands a realisation of the forests from whence the coal-fields were formed, then the forest-scenery of the carboniferous era was not devoid of elegant forms and pleasing aspects. Some imaginative writers on the geological history of the earth have produced pictures of that epoch from the scanty remains exhumed from its fossil beds, in which they depict very dismal restorations of its pristine scenery. To these we take exception, as their conclusions are not borne out by the analogous forest-scenery of New Zealand. This, however, they may dissent from; but we are of opinion that not only the extinct vegetation of the earth has its existing types, but also the animal creation that then existed. In a previous section of our work we have instanced Australia as an example of that epoch when animals were in a transition state from reptiles to mammals, as seen in the remarkable generative powers of the platypus and kangaroo. In like manner we may instance New Zealand as representing an epoch anterior to that in which reptiles were in their earliest stage—without a snake on the one hand, or a mammal on the other. Yet, notwithstanding the paucity of animal life and flowers, the forest-scenery of these islands is replete with the most elegant forms of plants. What it lacks in brilliancy and variety of colour the New Zealand forest makes up in beauty of form—from the tiny mosses to the gigantic arborescent ferns that chiefly compose its undergrowth of vegetation.

351. *Magnificence of the Tree-Fern Forests of New Zea*

land.—To resume the account of our first impressions on entering a New Zealand forest. We penetrated still further into its hidden recesses, attracted by the sound of one of the small cascades which are very numerous throughout the country. It was formed by a streamlet that leapt from rock to rock down a small ravine, sending the spray to the right and left on its rapid course. Over these waters, on each side, rows of tree-ferns bent their blackened stems, with their graceful pinnate fronds hanging more elegantly than any palm-tree. Some fronds were white underneath (*Cyathea dealbata*), others were dark and spotted with bundles of spores (*C. medullaris*), and some were bipinnate and pendant, from seven to twelve feet long (*Alsophila excelsa*). None were less than ten feet in height, and many of them reared their curled feather-like tops from forty to sixty feet high. It was a beautiful sight, and we could not but wonder how they attained such a height and luxuriance among the rocks, where the little soil that could collect about the roots was liable to be washed away by the heavy rains or the swollen stream. It was easily seen that they did not depend upon the earth for their sustenance, while they had such a supply of gaseous food from the water and air. Their roots served them merely as holdfasts to remain in a locality where the gaseous food upon which they throve was found in greatest abundance, and the generous stream scattered its spray broadcast among their fronds.

352. *Arborescent Ferns derive their Strength from Air and Moisture.*—On ascending the rocks to see further into this beautiful avenue of tree-ferns, we were still more enchanted with the scene on observing the smaller ferns that grew upon them and the rocky banks of the stream. Here were creeping ferns covering the rocks like ivy (*Trichomanes reniforme*); climbing ferns entwining the trunks of the trees (*Hymenophyllum flabellatum*); ferns hanging in festoons from tree to tree, like the vine planations in Italy, the fertile fronds looking like small grapes (*Lygodium articulatum*); others of the most delicate tracery, like the down of sea-birds, only

green in hue (*Todea pellucida*), and many others of fantastic yet elegant forms. But what most impressed us was the translucent nature of the fronds, which resembled the pellucid green of many sea-weeds, so that it required very little stretch of imagination to ally the two classes of plants together. And we could furthermore imagine that, among the rocky depths of the sea, the green *algæ* there would resemble the translucent ferns in a New Zealand forest. This view of cryptogamic vegetation growing in the sea on the one hand, and in the air on the other, may be witnessed on a small scale in our gardens of natural history. Here may be seen a Wardian glass-case enclosing many of the small pellucid ferns referred to, and the no less beautiful fern like moss (*Hookeria pinnata*), a link between the two families, flourishing within a moist atmosphere, which is continually supplied by its own evaporation and condensation. There we may find an aquarium, with pale-green sea weeds (*Lichinia*), or irridescent and fan-shaped (*Padina pavonia*), growing in fresh water, exhibiting the close analogy between water and air plants, when they do not depend upon the soil for their sustenance, but absorb at every pore the water, carbonic acid, hydrogen, and other elements that constitute the pabulum of their existence.

353. *Greater Volume of the Carbonic constituent in the South Aerial Hemisphere.*—From the foregoing data we naturally draw the inference that the atmosphere in New Zealand is more highly charged with carbonic acid gas than it is in Great Britain; and furthermore, taking the extent and geographical position of the two groups of islands into consideration, they are fair representatives of the condition of the atmospheric constituents in each hemisphere, or, at all events, within their temperate zones. Hence we extend the deduction from these premises, and infer that there is a greater volume of carbonic acid in the south than there is in the north hemisphere at the present day; while, in all probability, during the carboniferous era in Europe they were precisely equal, when the ferns of the coal-formation flourished even more

luxuriantly than their modern types do in New Zealand. But it may be advanced, in opposition to this conclusion, that the forests we have described as existing in that country derive their peculiar species of trees and shrubs, or, at all events, their growing to such a magnitude, from the intense humidity that prevails. In reply we might refer to analogous moist climates in the British Isles, such as may be found in the west Highlands of Scotland, where rain falls as constantly and heavily amongst the ferns and mosses that grow there; but they never reach the size and luxuriance their contemporaries attain at the antipodes, neither do they approach those of their extinct prototypes buried in the strata beneath where they grow. But we shall not rely entirely upon that evidence. There are abundant data in other regions of the south hemisphere, possessing very different climatic phenomena of an opposite character to humidity, where the vegetation presents striking examples of being highly charged with carbonic gas.

354. *Tropical Division of Australia, and its Humidity.*—Of these regions, the "Great South Land" of Australia presents the most remarkable and interesting specimens of the vegetable kingdom—growing in an atmosphere as intensely dry as that of New Zealand is moist. Although not more than twelve hundred miles distant, no two regions on the globe could present greater contrasts of climate in this respect, which imparts its influence to the vegetation and general aspect of each country. We have described the humidity of the one, and we shall refer to the aridity of the other, or rather to that division of the great island-continent that lies in the same parallels of latitude; for in its tropical division, north of Cape Capricorn, a rainy season prevails, as in India, when the forests are as humid as those in New Zealand. "This season commences generally about the end of October, and ceases in the middle of March, during which the greatest amount of heat occurs with the highest degree of moisture, as experienced in the Indies. This effect of its intertropical position distinguishes the climate of Queensland from the

other divisions of Eastern Australia as distinctly as its pine-forests (*Araucaria*) mark the boundary of vegetation. When the south-east trade-winds extend their influence during the summer solstice beyond the Tropic of Capricorn, they reach as high as 28° south latitude, and are no doubt the cause of these periodical rains. The precursor of this deluge is generally a thunder-storm, such as is seen only between the tropical zones. Masses of dense scud rise up from the Pacific Ocean towards the interior, until they are checked by the southerly wind blowing over the New England country. They then become packed into a uniform mass, shrouding the heavens. A stifling sultriness succeeds, and the lightning bursts forth from the lurid gloom, flash succeeding flash with fearful rapidity—now forked from the zenith, anon like a chain round the verge of the horizon—while the crash of thunder resounds like a park of artillery. The flood gates of the black canopy above are now opened, and the rain descends in torrents, with a noise like the pattering of a host of feet, amidst the war of elements. Soon the narrow tributaries of the rivers are swollen, some of them rising as much as fifty feet in twelve hours, when the banks are overflowed and the surrounding plains are deluged."*

355. *Aridity of the Temperate Regions of Australia.*—These periodical rains are succeeded by a dry season in tropical Australia, which lasts through the remainder of the year, when little or no rain falls. It is not, however, in that region we intend to point out the contrast of climate with New Zealand. We shall select the colony of Victoria, forming the most southern portion of the mainland, as affording evidence of its arid atmosphere within the temperate zone. Every summer, in all that extent of country, there blows a hot dry wind with such intensity that the ground is parched up, and vegetable activity seems almost to be arrested among indigenous plants, where no water or moisture is found. And what is deserving of notice is the circumstance that, while this aridity exists in the air at Melbourne about latitude 38°,

* 'The Gold Regions of Australia,' by Samuel Mossman.

the periodical rains are at their height near Brisbane, in 28° latitude. "The cause of this wind has not been satisfactorily accounted for by meteorologists, although its effects are pretty well known to the colonists of Victoria. When travellers inform us that the Egyptian sirocco proceeds from the Arabian desert, and the African simoom from the Sahara, we are justified in concluding that the far interior of Australia is of an equally barren and desolate nature—at all events during that season when these hot winds blow from the central north region to the southern coast. Its approach is heralded by similar indications. A fine dust pervades the atmosphere, clouds disappear, and a lurid gloom prevails. The hot blast from a gentle breeze increases to all the fury of a tempest, until its strength is expended. Its effect upon cultivated vegetation is desolating, and, but for its short continuance, would be equally destructive to men and animals. As it is, it produces sufficiently bad effects upon the human constitution, in causing ophthalmia, inflammatory attacks, and determination of blood to the head."

356. *An Australian Sirocco during Summer in Victoria.* —"It occurs generally about the end of January or the beginning of February, and seldom continues longer than two days and three nights. As the province of Victoria enjoys the coolest climate of the mainland colonies, so does it experience the hottest blasts of this sirocco. The inhabitants of Melbourne, Geelong, and their suburbs, dread its approach; for seldom a season passes over without considerable loss to the colonists. Although its effects are not deadly, yet they are sufficiently uncomfortable to class this blighting annual visitor as the greatest drawback to the otherwise salubrious climate of the colony. Its approach is indicated by the wind veering to the north, generally occurring about ten o'clock in the morning. By noon there is a sensible change in the state of the atmosphere, producing a parched state of the tongue and lips, and heated dilatation of the nostrils, the thermometer rising to 100° Fahrenheit in the shade. From the dry state of the air no immediate enervating effects follow this

high temperature; but, as the wind increases, it becomes charged with minute particles of sand and burnt vegetation, which have been felt at sea ninety miles from the land. The dust from the roads and streets next rises in mutiny, while the sun glares out fiercely, causing the persecuted inhabitants of the towns to shut out the unwelcome visitor, and betake themselves to cellars and darkened rooms for shelter."

357. *A Hot Wind at Melbourne described.*—"In Melbourne its effects are particularly disagreeable. As the sun goes down on the evening of the first day there is a slight lull in the breeze, and the thermometer falls below 90°, so that the inhabitants can manage to sleep until sunrise. No sooner, however, does the glaring orb, magnified by the haze, look forth upon the dusty town, than the wind increases in violence and intensity of heat, blowing in gusts that tear the branches from the trees and endanger ships in harbour. By noon the people close the shutters of their windows, and fasten the doors and apertures to prevent the ingress of the impalpable powder, which covers every article of furniture and food. Although oppressive to suffocation indoors, it is nothing to the hot blast that greets you in the street if you attempt to go outside. Business is suspended, unless it be to purchase drinkables and the necessaries of life. The clerk at his ledger feels the boards bending backwards, and the leaves curling up. The principal occupation of the inhabitants is to moisten their parched throats by eating water-melons and drinking all manner of liquids, which can be enjoyed to a superlative degree in the spacious saloons and cellars built on purpose in most of the hotels."

358. *Forests and Pastures on Fire during the Hot Winds in Victoria.*—"Meanwhile it is evident that the dry grass at this season of the year is still more parched by its influence, and has caught fire in the environs of the town. Clouds of smoke now add to the stifling gale, and the heavens become obscured as if there was a thunder-storm gathering. The restrained action in breathing becomes almost insupportable if you are in the forest, and the half-suffocated settlers have a

difficulty in stopping the progress of the burning grass towards their homesteads. The sheep lie down with faintness, and the cattle and horses gallop about in wild delirium amongst the burning grass and trees. The scene all around is fearfully wild. Here the flames have entered some dense brushwood, blazing and crackling amidst the heavy smoke from the green bushes and trees, which at length ignite from the combined effects of the hot blast and the dry, smouldering, dead timber. Then over the plains the flames rush along the grass with the speed of a race-horse, whilst above, wheeling in the air, are seen myriads of crows and birds of prey, swooping down upon the roasted insects, snakes, and small animals that have fallen a sacrifice to the conflagration. Thus upon the afternoon of the second day the hot wind reaches its climax, the thermometer stands at 117° in the shade, and the gale blows in wild and furious gusts. The disappearance of the sun brings very little cessation to the war of elements, and a sleepless, uncomfortable night is before the inhabitants. Scarcely a house in the town but shows a light from the windows, at which the inmates may be seen, clad in their lightest apparel, endeavouring to while away the sultry hours. Towards the opening of the third day the blast shows symptoms of abating, and continues to decrease gradually every hour until the evening, almost heedless of the effects produced by the noonday sun, pursuing evidently its more powerful nature, until, by the close of the day, its last hot breath is expended, allowing the cool south wind to step in and fill its place. The grateful breeze comes refreshing to the fevered cheeks of the colonists, and they lay down their heads to rest with some hopes of sleep." *

359. *Open and monotonous Aspect of the Forest-Scenery in Australia.*—With such a remarkable contrast in climate it may be supposed that the characteristic aspect of Australian forest-scenery differs considerably from that of New Zealand. There the atmosphere is dry, the trees are wide apart, with tap-roots hidden in the deep alluvial soil, and the foliage is

* 'The Gold Regions of Australia,' by Samuel Mossman.

of a coriaceous texture, sustained by aromatic oils to resist the hot winds. No underwood or jungle of creepers bars the way over the level forest-lands, while the ground is smooth and grassy, and free from surface-roots, so that the traveller can drive through these natural parks in a vehicle for hundreds of miles without any serious impediment. Elsewhere we have described how the leaves of the gum-trees (*Eucalyptus*)—which form the chief proportion of timber trees in these open forests—are evergreen, and they hang on the leaf-stalks with their edges upwards, both sides of them being the same, something like the leaves of the mistletoe. Compared with the foliage of European forest-trees the leaves are small, generally of a lanceolate shape, approximating to that of the common willow or ash. There are no umbrageous trees like the sycamore, and few have leaves as large as the elm. Hence these forest-lands are always open to the sunshine, and swept by the breeze, down to the herbage and flowers that cover the ground, affording pasture for the herds and flocks of the colonists. So striking is the open aspect of these forest-lands that the settlers compare it to the park scenery of England. In our travels through them, we have sometimes felt it difficult to divest ourselves of the idea that we were not riding through a nobleman's park, expecting to get a glimpse of some grand mansion between the trees, although nothing was seen but the bark hut of a shepherd, or the simple *mia-mia* of the aborigines. It must be observed, however, that with all this pleasing aspect, there is great monotony in this forest-scenery throughout the year, in consequence of the evergreen foliage and its dull tint. There are no bright hues in spring, with buds shooting from the boughs, or the varied shades of foliage in autumn, which give such charms to deciduous forest-scenery.

360. ***Australian Gum-Trees the highest Trees in the World.***—Although the leaves of Australian trees are small and scanty compared to those of Europe, it does not follow that they are less in height. On the contrary, there are giant gum-trees that would dwarf the largest sycamore, elm, or oak in Eng-

land, and rival the monarchs of the American forests. On this point the government director of the Botanic Garden at Melbourne furnishes some interesting details, as follows:—"The marvellous height of some of the Australian, and especially the Victorian, trees, has become the subject of closer investigation, since of late—particularly through the miners' tracks—easier access has been afforded to the back-gullies of our mountain-system. Some astounding data, supported by actual measurements, are now on record. The highest tree previously known was a *Karri-Eucalyptus* (*Eucalyptus collossea*), measured by Mr Pemberton Walcott, in one of the delightful glens of the Warren River in Western Australia, where it rises to approximately 400 feet high. Into the hollow trunk of this Karri, three riders, with an additional pack-horse, could enter and turn in it without dismounting. At the desire of the writer of those pages (Dr Mueller), Mr D. Bogle measured a fallen tree of *Eucalyptus amydalina*, in the deep recesses of Daudenong (Victoria), and obtained for it the length of 420 feet, with proportionate width; while Mr G. Klein took the measurement of a eucalyptus on the Black Spur, ten miles distant from Healesville, 480 feet high. . . . It is not at all likely that in these isolated inquiries chance has led to the really highest trees, which the most secluded and the least accessible spots may still conceal. It seems, however, almost beyond dispute that the trees of Australia rival in length, though evidently not in thickness, even the renowned forest-giants of California, *Sequoia Wellingtonia*, the highest of which, as far as the writer is aware, rises, in their favourite haunts at the Sierra Nevada, to about 450 feet. . . . Thus to Victorian trees the palm must be conceded for elevation. A standard of comparison we possess in the spire of the Minster at Strasburg, the highest of any cathedral in the world, which sends its lofty pinnacle to the height of 466 feet; or in the great pyramid of Cheops, 480 feet high, which, if raised in our ranges, would be overshadowed probably by eucalyptus trees."

361. *Dr Mueller's Account of the Australian Jungle.*—

These gigantic trees are not found in the open forests alluded to, but among the mountains, where deep rocky glens afford the moisture and shade necessary for their growth, denied to them in the arid level lands we have described. There the humidity is almost as great as it is in New Zealand, especially if the forests are near the sea. They are especially observable in the Australian Alps, and along the Cordillera, trending from the most southern to the most northern mountain-ranges parallel with the east coast. These dense forests are called "scrubs" by the colonists, to distinguish them from the open forests we have described, and "jungle" by Dr Mueller, as they present an aspect similar to that of the jungles in India. In his essay on 'Australian Vegetation' he remarks on its leading features as follows:—"While the absence of very high and wooded mountains imparts to the vegetation throughout a vast extent of Australia a degree of monotony, we perceive that the occurrence of lofty forest-ranges along the whole eastern and south-eastern coast changes largely the aspect of the country, and in this alteration the mountainous island of Tasmania greatly participates. Thus the extensive umbrageous forest-regions of perpetual humidity commence in the vicinity of Cape Otway; extend, occasionally but not widely interrupted, through the southern and eastern part of Victoria, and thence, especially on the seaside slopes of the ranges, throughout the whole of extra and intra-tropical East Australia in a band of more or less width, until the cessation of elevated mountains on the northern coast confines the regions of continued moisture to a narrow strip of jungle-land margining the coast. In this vast line of elevated coast-country, extending in length over nearly 3000 miles, and which fairly may pass as the 'Australian jungle,' the vegetation assimilates more than elsewhere to extra-Australian types, especially to the impressive floral features of continental and insular India. Progressing from the Victorian promontories easterly, and thence northerly, we find that the eucalypti, which still preponderate in the forests of the southern ranges, gradually forsake us, and thus in Eastern

Gippsland commences the vast assemblage of varied trees, which so much charms by its variety of forms, and so keenly engages attention by the multiplicity of its interest." It must be understood that this is exceptional to the general characteristics of Australian forests in the temperate latitudes, especially in the interior where extensive aridity and sameness make the rule.

362. *Rapidity of Growth in Australian Gum-Trees and Acacias.*—Although the colossal trees referred to by Dr Mueller, and the dense vegetation he describes, exist chiefly in the humid glens of the mountain-ranges, yet, even in the arid plains and undulating grassy lands, the gum-trees exceed in height the trees of European or American forests generally; while the acacias, which form a large section of the trees and shrubs in Australia, grow luxuriantly in dense groves where ordinary plants would be stunted or perish. There is a rapidity of growth observable in the vegetation generally that surpasses anything known in the north hemisphere, to account for which we naturally return to the first principles involved, and conclude that this is fostered by the presence of carbonic acid gas in greater volume. The evidence furnished by Dr Mueller on this point is as follows:—"Not merely in their stupendous altitude, but also in their celerity of growth, we have in all probability to accede to Australian trees the prize. Extensive comparisons instituted in the Botanic Gardens of Melbourne prove that several species of eucalyptus, more especially *Eucalyptus globulus* and *Eucalyptus obliquus*, as well as certain acacias—for instance, *Acacia decurrens*, or *Acacia mollissima*—far excel in their ratio of development any extra-Australian trees even on dry and exposed spots, such as those into which our blue gum-trees would not penetrate spontaneously. This marvellous quickness of growth, combined with a perfect fitness to resist drought, has rendered many of our trees famed abroad, especially in countries where the supply of fuel or of hardwoods is not readily attainable, or where for raising shelter, as around the cinchona plantations of India, early and copious command of tall vegetation

is of imperative importance." Of course this would depend upon the elementary food of these plants being as abundant in their exotic localities as it is in their indigenous habitat.

363. *Evidences of a large Volume of the Carbonic Constituent in the Atmosphere of Australia.*—Now, in accounting for this rapid and gigantic growth of trees and shrubs in Australia, we have not the same phenomenon as that presented by New Zealand vegetation—of the plants absorbing their carbonic acid gas from the atmosphere through their surface-roots. On the contrary, the eucalypti have tap-roots that penetrate into the deep alluvial soil, like the trees of Europe. But we have evidence that this soil itself is highly charged with carbonic acid gas, which acts as a great deodoriser and destroyer of noxious gases to animal life. Hence Australia is famed for its hygienic advantages and the absence of malaria from its marshy lands—a quality in which the climate of New Zealand participates, as also those of South Africa and South America. This branch of our subject we shall not enter into at present, as it will demand our attention in discussing the extraordinary salubrity of the south aerial hemisphere generally for human beings and all lung-respiring animals. Meanwhile we shall proceed to inquire how far the peculiar nature of the evergreen leaves of Australian trees affords evidence of the presence of an atmosphere more highly charged with carbon than is found in regions where deciduous trees are indigenous.

364. *Evergreen Characteristics of all the Vegetation in the South Hemisphere.*—Evergreen shrubs are well known everywhere, and are much prized from their leaves continuing to adorn the plants when the great mass of vegetation is stripped bare, such as the myrtle and laurel of Europe. The same may be said of pine-trees and their congeners; but the needle-like size and form of the leaves makes them conspicuous among the foliage of broad-leaved forests. It will, however, be admitted on all sides that evergreen shrubs and trees are exceptional to the general character of the vegetation throughout the north temperate regions, and that, as a rule, the trees there are deciduous, or, in other words, they shed their leaves

annually—a phenomenon which occurs with such certainty in the North American regions, that it has given rise to the household word of the "fall" of the year, as the season of all others most marked among the four. On the other hand, throughout the south temperate regions this peculiarity of the vegetable kingdom is reversed; the ruling character of the trees and shrubs is evergreen, and the exceptional deciduous plants are small annuals that form but an infinitesimal part of the vast zone of vegetation. As far as we know, there is probably not a deciduous species of tree or shrub indigenous to any country in the southern hemisphere. This we do not point out as an advantage possessed by the vegetation there over the contemporary *flora* of the north hemisphere, but simply as a fact that deserves further investigation, with a view to determine the causes that produce the phenomenon. Viewing the subject in a popular light, we incline to an admiration for deciduous vegetation, which associates with its budding, blossoming, and decay, so many analogous features to the great phases in human life. Mr Darwin has the following characteristic remarks on this subject:—"In South America, Australia, and the Cape of Good Hope, the trees are all evergreens. The inhabitants of these and the intertropical regions generally thus lose, perhaps, one of the most glorious, though to our eyes common, spectacles in the world—the first bursting into foliage of the leafless tree. They may, however, say that we pay dearly for our spectacle by leaving the land covered with the more naked skeletons for so many months. This is too true; but our senses thus acquire a keen relish for the exquisite green of the spring, which the eyes of those living within the tropics (and in the south temperate regions), sated during the long year with the gorgeous productions of those glowing climates, can never experience."

CHAPTER XVII.

DIFFERENCE BETWEEN THE VEGETATION OF THE NORTH AND SOUTH HEMISPHERES. *Continued.*

Causes that produce deciduous vegetation in the north hemisphere, § 365. Absorption of carbon and exhalation of oxygen by leaves, 366.—Negative evidence of disparity of carbonic constituent in the two hemispheres, 367.—Theory accounting for the domination of carbonic acid gas in the north hemisphere, 368.—Limited extent of coal measures in the south hemisphere, 369.—Australian araucarias analogous to extinct conifers, 370.—Analogy between the plants and animals of Australia and those of the carboniferous era, 371.—New Zealand a region of modern formation without any indigenous mammals, 372.—Darwin's account of immense Kauri pines in New Zealand, 373.—European annuals grown in southern regions become perennial, and deciduous trees evergreen, 374.—A brief description of a cycle of the seasons in Victoria, Australia, 375.—Spring grasses parched, yet the pasturage nourishing, 376.—Summer siroccos, 377.—Autumn a second spring, 378.—Winter storms and rains, 379.—Droughts of long continuance, 380.—The seasons in New Zealand favourable for agriculture, 381.—Fertility of crops attributed to the large supply of carbonic acid gas in the air, 382.—Difference in volume of constituents evidence that the particles of the air do not universally intermingle, 383.

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365. *Causes that produce deciduous Vegetation in the North Hemisphere.*—With regard to the causes that produce the phenomena of deciduous vegetation, there is no doubt that a low degree of heat in the atmosphere forms an important auxiliary; but it is not the chief cause in producing the fall of the leaf, as popularly understood. "Although the fall of the leaves generally takes place at the approach of

winter, cold is not to be considered as the principal cause of this phenomenon. It is much more natural to attribute it to the cessation of vegetation, and the want of nourishment which the leaves experience at that season, when the course of the sap is interrupted. The vessels of the leaf contract, dry up, and soon after that organ is detached from the twig on which it had been developed. The various tints of the autumnal leaf yellow, red, brown are owing to the different degrees of oxidation of the matters contained in the desiccated juices of the leaf; not unfrequently the colour is influenced by numerous minute fungi which spring up on the surface of the decaying leaf. How beautiful are the mellow tints of an autumn forest! more deep and gorgeous, though not so full of hope and joy, as the light budding appearance of spring." *

366. *Absorption of Carbon and Exhalation of Oxygen by Leaves.*—It is not necessary to go into any detail to show the importance of air to the life of plants, and the absorption of moisture and gaseous elements by the leaves; suffice it to say that it has been satisfactorily proved that an entire plant, root, stem, and leaves died very shortly after being placed under the exhausted receiver of an air-pump; that another plant lived with its root and stem in the vacuum, and its leaves exposed to the influence of the air; so that the leaves of plants are equivalent to the lungs of animals. "Modern chemistry has afforded us many other proofs of the functions of the leaves of plants. The experiments of Priestley, Ellis, Decandolle, and others, have fully established both the absorption and exhalation of gases through the medium of the leaves. . . . The decomposition of the carbonic acid absorbed from the air is effected in the parenchyma of the leaves, as well as in all the other green and herbaceous parts of the vegetable. When vegetables are exposed to the action of the sun they are decomposed, the air retaining the carbon and disengaging the oxygen. The reverse takes place when they are withdrawn from the influence of the light, in which case they extract from the air a portion of its oxygen, which they

* '*A History of the Vegetable Kingdom.*' *By William Rhind.*

replace by disengaging an equal quantity of carbonic acid gas." In other words, the green part of plants, exposed to the direct rays of the sun, enjoy the property of decomposing the carbonic acid gas contained in the atmosphere, and setting at liberty an equivalent quantity of oxygen. In the dark the contrary takes place: oxygen is absorbed, and carbonic acid gas evolved at the expense of the plant. A French *savan*, M. Caillet, has recently made some further experiments on this subject, which we find described in the 'Journal des Connaissances Medicales.' He has ascertained that fresh leaves, even when separated from the stalk, will act on gaseous mixtures besides the atmosphere as if they were still adherent; and that leaves of the same plant having an equal surface will decompose the same quantity of carbonic acid gas when they act on identical mixtures. Leaves either crushed or rubbed lose the property alluded to; but they will not be entirely deprived of it if cut into small bits. The decomposing action requires a temperature of from 50° to 60° Fahrenheit; but rays of dark heat are not sufficient to produce it. Coloured rays act with various intensities; green will decompose no carbonic acid gas at all—a circumstance which explains the reason why vegetation is languid under the imperfect shade of large trees. Thus it appears, from the highest authorities, that carbon in a gaseous form is the chief element in supporting the vital condition of trees as well as shrubs, and that its absorption and exhalation are the principal functions of the leaves. Hence it follows that the evergreen vegetation of the south hemisphere performs these offices perpetually, which are in a measure suspended during half the year among the deciduous plants of the north hemisphere. This may account for the excessive rapidity of growth observed by Dr Mueller in the eucalyptus and acacia families in Australia, showing this to consist not in actual quickness of development, but that they do not slack in their speed in the flora race; while their antipodean competitors lag behind during winter.

367. *Negative Evidence of disparity of Carbonic Constituent in the two Hemispheres.*—Whatever inferences we

may draw from the contrast in the vegetation of the two hemispheres, it is clear that this greater carboniferous development of plants can arise from no other cause than that the temperate zone of the south aerial hemisphere is more highly charged with carbonic acid gas than the corresponding zone in the north. And, further, that deciduous vegetation arising during an epoch subsequent to a period when a highly carbonic flora became extinct, imbedding carbon in the coal-fields, it follows that the north aerial hemisphere has been partially exhausted of this element so essential to evergreen vegetation, and a new deciduous flora superinduced. In consequence of this diminution of carbon in the air, constituting the principal pabulum of vegetable existence, we find that the atmosphere has its geological history as well as the land and sea. If we could obtain vestiges of its primeval condition, in all probability we would find extraordinary changes in the volumes of its constituents through various epochs to the present period. In the strong negative evidence furnished by the foregoing data—that the atmosphere in the south temperate regions contains a larger percentage of carbonic acid gas than in the north—we have a vestige of importance for our consideration, if subsequent investigation by analyses and positive proofs demonstrate its correctness. Assuming that this disparity exists, it may be accounted for geologically in the following manner:—

368. *Theory accounting for the Diminution of Carbonic Acid Gas in the North Hemisphere.*—Let us suppose that at a period in the physical history of the earth the atmosphere on both sides of the equator was well provided with the carbonic element, and there was no vegetation above the level of the sea to absorb it. Then came the upheaval of the land in the north hemisphere, upon which enormous forests grew, the trees and shrubs of which they were composed absorbing largely this necessary element of their existence. Although by their functions these plants returned back through exhalation into the air a part of this carbon, yet the bulk entering their structure in an indestructible form was buried in the

ground, and through the agency of volcanic heat became coal. When we consider the immense area and depth of the coal-measures throughout the British Isles alone, and the infinitesimal proportion of carbonic acid gas in the air, we can easily imagine how it has been partially exhausted. And if we extend this observation to the great known, and probably greater unknown, coal-deposits in North America and the Asiatic continent, we can understand how the atmosphere in these regions has been so reduced in carbon that it could no longer maintain the class of plants that formed the coal-fields. Then they became extinct, or, their functions becoming adapted to the altered condition of the air, the hardiest plants lived through the season when divested of their foliage, while new genera of trees and shrubs of a deciduous nature, requiring less carbonic sustenance, sprang up to fill the places of the evergreens. In the south aerial hemisphere during those periods of exhaustion in the north, the atmospheric constituents remained almost unaltered in their primitive volume, as there was but little land upheaved above the sea-level compared to the vast area of water, and the vegetation capable of forming coal-fields was of a very limited character, if we may judge from the few known deposits and the rare indications of their existence in southern regions at the present day.

369. *Limited Extent of Coal-Measures in the South Hemisphere.*—In Australia it is true that coal mines have been opened in several localities, and the mineral forms a valuable article of export from the colony of New South Wales. But these, without detracting from their importance, are of small area and bulk compared to the extent of country in which they occur. The largest coal-field forms great part of the Hunter river basin, about one hundred miles north of Sydney, and the next is in the district of Illawarra. There are other known seams in that colony, as well as Victoria, Queensland, Tasmania, and Western Australia, but the coal is of such inferior quality, or is so badly situated for carriage to a profitable market, that scarcely any of it is utilised. So important is this article in the estimation of national wealth, that in these

colonies, as in the mother-country, government inspectors and geologists are appointed to report upon its quality and extent of deposit. In the published reports of these officials for Victoria and New South Wales, an interesting controversy has been raised regarding the geological age of Australian coal. Professor M'Coy, in the former colony, holds that there is scarcely any evidence to show that it belongs to the ancient carboniferous period in the north hemisphere; while he classes it under the more recent miocene period of the tertiary formations. On the other hand, Mr Keene, government examiner of coal fields in the latter colony, backed by the Rev. Mr Clarke, an enthusiastic geologist, stoutly defends the following statement:—"The lower beds of the coal series of New South Wales are geologically older than any worked in Europe, whilst the upper beds represent the most recent of the European true carboniferous formation. And as all the coal-seams from the Silurian upwards are deposited conformably, I must conclude that this portion of the globe was comparatively free from violent eruptions and disturbances from the Silurian to the Permian epoch, and that the alternate submergences and elevations of the land must have been slow and gradual." This controversy does not affect much our theory of the diminution of carbon in the atmosphere, as it would not matter during what period it took place, provided the extent of the coal-measures showed an amount of this element buried in the earth equivalent to what exists in the northern coal-fields. For example, if we heard of coal being found in South Africa as abundantly as it is known to exist in China, or, what is more apposite, if it occurred in South America, like the inexhaustible coal-measures of North America, we should then have evidence of great abstraction of carbonic gas from the primeval atmosphere in the south. As it is, we hear almost nothing of coal being found in these regions; so that altogether the land in the south hemisphere, besides being not one-third in superficies to that of the north, is remarkable for its paucity of coal, or those formations indicating its presence. Hence we draw the inference that the

atmosphere in that binary division of the earth retains at present nearly the same volume of carbonic acid gas that it had during the ante-carboniferous period.

370. *Australian Araucarias analogous to extinct Conifers.*—Besides the tree-ferns that connect the living flora of Australia with the extinct flora of Europe, there are examples of the *coniferæ* that do so too. Botanists have observed in their microscopical examination of woody tissues peculiar punctated or disc-bearing markings on the thin walls of the cells, as if they were indented, and giving them the appearance of dots. They occur chiefly in the timber of pine-trees in Europe and America, forming single rows along the tissue, but not in any great abundance. On examining thin sections of the fossil conifers, these dots have been observed to be more numerous, and forming double rows of markings. When sections of the Australian conifers of the genus *araucaria* were submitted to microscopical inspection, they presented identical double dotted tissue to the carboniferous pines, proving the close alliance between the extinct flora of the north and the living flora of the south, and, *cæteris paribus*, a similarity in the atmospheric constituents of the two hemispheres which no longer exists. Moreover, while the extinct pine-trees of the coal formation in the north differ in their structure from the existing pines of Europe and America, the fossil conifers found in the carboniferous strata of Australia, as exemplified in the shale of the Hunter river coal-mines, are identical in structure with the living araucarias growing not far north of that locality.

371. *Analogy between the Plants and Animals of Australia and those of the Carboniferous Era.*—When we add this fact of vegetable analogy to that discovered between the extinct and existing zoology of the past and present organic life of the earth, we are drawn into an interesting study of Australian physical history. In the first division of our subject we alluded to the remains of marsupial animals having been found in the earlier tertiary deposits. These are the oldest remains of mammalia yet exhumed and date as far back as

the oolite period. "They are marsupial quadrupeds, *Amphitherium Broderipii*, *A. Prevostii*, and *Phascolotherium Bucklandii*. They occur in the Stonesfield slate, and as yet but few relics of these interesting extinct creatures have been found." * Notwithstanding the scarcity of their remains, there is sufficient evidence for such skilful zoologists as Professor Owen to determine the identity of these extinct animals with the living kangaroo (*macropus*) and the sloth (*phascolarctos*) of Australia, which is specially characterised in the geographical division of the distribution of animals as the region of *marsupialia* or pouched animals. These analogies lead to an interesting inquiry, whether Australia, or, at all events, its mountain-chains on the east and west coasts, are coeval with the extinct epochs of the north, retaining its *flora* and *fauna* undisturbed up to the present period; or whether, being upheaved under an atmosphere retaining its primary volumes of gaseous constituents, its natural history commences at the lower scale of creation before it can reach the higher classes of plants and animals found in the north aerial hemisphere. We confess that this is a subject requiring further investigation; at the same time, according to the general theory propounded in this essay, we would draw the inference that Australia, and all the adjacent isles forming the fifth geographical division of the world, which the English name Australasia, are in an embryo state of animal and vegetable life. Our views at one time inclined to the hypothesis of contemporary antiquity with the earliest epochs of aerial organic life, from the hitherto unquestioned theory of geologists and zoologists, *that all species of animals and plants throughout the world, from pole to pole, must have existed at the same time, as they present a similar development in the order of creation.* To this universally received theory we take exception, upon the ground that it is not carried out in the *fauna* and *flora* of Australasia, where indigenous life is more or less rudimentary at the present advanced period of the earth's history.

* Johnston's 'Physical Atlas.'

372. *New Zealand a Region of Modern Formation without any indigenous Mammals.*—If there is room for doubt on this point with regard to Australia, there can be little or none in the case of New Zealand, where the whole mass of vegetation is of the lowest type, and no indigenous mammal exists; while the formation of the group of islands is modern, volcanic, or recent sedimentary deposits. To the most superficial observer their general aspect is that of new regions not long emerged from the depths of the Pacific; and the investigations of naturalists and geologists go far to confirm that impression. Though there are no trees in New Zealand belonging to the genus *araucaria*, yet there is one conifer differing from all others, fossil or living, that will compare favourably with them as a tree typical of carboniferous properties. This is the Kauri pine (*Dammara Australis*), and the only New Zealand pine that bears a cone—all other kinds producing some species of berry—and therefore to be classed amongst the very numerous family of *podocarpi* or *taxidea*. This magnificent tree, which grows to a very great size, flourishes only in the North Island, in the neighbourhood of the sea-coast, and generally in mountainous situations, though we have seen some small inland forests of it on level ground. Being a valuable article of commerce, for the excellence of its spars for the largest men-of-war, and its close-grained timber for planks, it has attracted more attention than any other description of tree in the country.

373. *Darwin's Account of immense Kauri Pines in New Zealand.* — Darwin furnishes the following account of the gigantic dimensions of this tree :—" I measured one of those noble trees called the Kauri pines, in a part that was not enlarged near the roots, and found it to be thirty-one feet in circumference. There was another close by, which I did not see, thirty-three feet, and I heard of one not less than forty feet. The trunks are also very remarkable for their smoothness, cylindrical figure, absence of branches, and having very nearly the same girth, with a length from sixty to ninety

feet. The crown of this tree, where it is irregulary branched, is small and out of proportion to the trunk, and the foliage is likewise diminutive as compared with the branches. The forest was almost composed of the Kauri, and the largest, from the parallelism of their sides, stood up like gigantic columns of wood. The timber of these trees is the most valuable product of the island (north); moreover, a quantity of resin oozes from the bark, which is collected," and manufactured by the Americans into a varnish of superior quality.

374. *European Annuals grown in Southern Regions become perennial and deciduous.*—Besides the property of rendering indigenous vegetation evergreen and perennial, the south aerial hemisphere has apparently the power of imparting these qualities to trees and shrubs transplanted from the north hemisphere. When the colonists in the environs of Brisbane, Queensland, first imported the cotton-plant from North America, they obtained seeds of the annual herbaceous kind, known as the "Sea Island Cotton," prized for its superior quality, and yielding the most valuable produce of all varieties. After a few years' cultivation the settlers were agreeably surprised to find that the plant assumed a perennial character—thereby obviating the expense and trouble of growing it annually from the seed. At the Cape of Good Hope, the traveller, in proceeding along the excellent roads made by the early Dutch colonists, may observe, among the trees that shadow the way, a number of oak trees, which on inquiry he is informed belong to a species called the African oak, and that its leaves are evergreen. He may suppose that it is the holly, holm, or evergreen oak of Europe (*Quercus ilex*); but there are data for concluding that they are descendants from the deciduous oak (*Q. robur*) which the Dutch imported more than a century back, and it has since become an evergreen. In New Zealand, the oak, the ash, the horse-chestnut, and the walnut grow luxuriantly, with a tendency to retain their foliage longer than in Europe, but they cannot yet, although in time they may, be classed as evergreens.

There, also, in the gardens, many plants which are annual in England have become biennial and perennial. These noticeable changes in the plants imported for use or ornament by the settlers in the Australian or New Zealand colonies are attributed by them to the geniality of the climate compared to what they have been accustomed to. But we contend that it arises from the difference in the vital functions of the atmosphere, induced by the presence of a larger volume of carbonic acid gas.

375. *A brief Description of a Cycle of the Seasons in Victoria, Australia.*—It is well known that the seasons occur in those southern regions during the opposite months of the year to what we experience in our northern climate. Likewise, as we have elsewhere shown, the winter season is short and not so rigorous, while the summer season is longer and hotter. These characteristics are most strikingly exemplified in Australia, where snow is almost unknown, and frost is of short duration on level-lands near the sea. As the climate of the colony of Victoria embraces all the phenomena of the seasons in the temperate latitudes of that region, we shall quote from the report of Mr Ellery, the local government astronomer, "a brief description of a cycle of the seasons." In this he has adopted the popular division of each season into three months' duration, which is not strictly correct, as far as nature is the interpreter. This is especially noticeable under the head of Autumn, where the character of the season is reversed—as observed in a previous section of our work—and which he describes as constituting a second spring. With these exceptions, the account, as follows, of the seasons at our antipodes is graphically correct, and no doubt will be interesting to the reader who has not experienced the glowing heat of Christmas-day in Australia :—

376. *Spring Grasses parched, yet the Pasturage nourishing.*—"The spring season, which may be said to include September, October, and November, generally sets in about the beginning of September, during which month, although slight frosts sometimes occur, the weather is usually mild and

often quite warm. Rather above the monthly average of rain also frequently falls. Strong northerly and westerly winds are prevalent in September and October, but the currents of air, both as regards frequency and velocity, seem to be more equally distributed during these months than at other parts of the year. The northerly winds begin to assume the dry and warm condition that characterises them throughout the summer months; and it is not at all unfrequent that quite a hot wind may prevail for a short period even in October; the weather generally, however, in September and October, is genial and pleasant. November also, representing the height of spring, is usually characterised by fine, warm, and sometimes even hot weather. It is not at all unusual to get a large rainfall in October or November, sometimes giving rise to extensive floods; in some seasons, however, the rainfall after the commencement of October diminishes considerably, and frequent dry and even hot northerly winds in November parch the grass and other herbage, giving to the plains and hills a sand-like appearance; but in others the pasture remains green till January, and in many parts of the colony throughout the year." [Notwithstanding this parched appearance of the grass, it retains its nourishing properties for herbivorous animals—the imported sheep and cattle thriving well upon the pasture of these indigenous grasses, where European grasses would afford none. This arises from some of the former having solid stems, with a kind of pith, which enables them to resist the blighting effects of the hot winds, under which hollow-stemmed grasses, such as the latter, would shrivel up and crumble into dust.]

377. *Summer Siroccos.*—"The summer season includes the months of December, January, and February. December is often marked by very changeable weather, and, although generally hot and dry, it is not unfrequently broken up by cold and stormy intervals, with heavy rains and gales of wind. The northerly winds become more or less hot according to the amount and distribution of the rainfall throughout

the interior during spring. Very great changes of temperature often take place in a few hours; for instance, a warm north wind prevails in the morning, with a temperature reaching as high as 90° or 100°; a lull in the afternoon is quickly followed by a strong breeze from the S.W., and the temperature becomes reduced to 65° or 60° in fifteen or twenty minutes. The highest mean temperature occurs in January; February, also, is often characterised by great heat and dryness. It is during these months that the northerly winds become perfect siroccos for short periods, and if the spring has been dry, extensive bush-fires occur on the plains and in the forests, giving rise to a considerable increase of temperature, and superadding to the already unpleasant state of things a smoky and lurid atmosphere over considerable areas in the vicinity. Although unpleasantly hot weather very frequently intervenes throughout the summer months, yet a large, and often the largest, portion of the weather is fine and pleasant, with cool southerly or south-westerly winds.

378. *Autumn a second Spring.*—"The autumn season, including the months of March, April, and May, although subject to stormy weather, gales of wind, and large rainfall—especially in its earlier part, and following the equinoxes—may nevertheless be called the most genial and beautiful portion of the year. *It constitutes a second spring; for so soon as vegetation receives the moisture it has thirsted for during the summer, the indigenous plants and trees put forth a growth that often exceeds that of spring.* The temperature on the whole maintains a moderate mean; the northerly winds now become cooler, and solar radiation is considerably reduced; heavy dews fall at night, and sometimes towards the end of this season fog occurs during the night and early morning in very calm weather. In April the mean temperature is 59°, and in May 53°.

379. *Winter Stormy and Rainy.*—"Winter includes June, July, and August. This season, though usually marked by frequent rains and strong winds, especially from the north, is in some years remarkably dry, with a small rainfall; the

temperature does not reach its minimum till the middle of July and the beginning of August, and seldom in Melbourne falls much below freezing point. Ice and hoarfrost occur generally only on a very few occasions during the winter in the neighbourhood of Melbourne—the former sometimes attaining a quarter of an inch in thickness. At higher levels, however, frost and ice have been observed as early as May, and form much more frequently during the winter months than at the lower levels; the highest mountain-summits, too, are in most seasons seen to be clothed in snow by June, and sometimes as early as the beginning of May. The strongest winds in winter are usually from the north, from which quarter it often blows with great violence: wind from this direction is dry, and usually very cold at this season."

380. *Droughts of Long Continuance.*—"The worst vicissitude to which the climate of Victoria is subject, in common with Australia generally, is the occasional droughts. These, as already stated, appear to follow those years characterised by unusual rainfall—a fact that has given rise to conjecture that both the excessively wet and the excessively dry seasons are periodical. The last drought to which the colony was subject extended from the summer of 1865 to almost the winter of 1866, and was doubtless due to the small rainfall in the autumn and spring months."

381. *The Seasons in New Zealand favourable for Agriculture.*—In New Zealand the recurrence of the seasons approximates more nearly to that of the British Isles than any other region in the south hemisphere, on account of its insular position, and the cool latitudes the southern islands are placed in. "Generally speaking, the seasons may be said to be retarded as well as reversed from those of England—that is, continued fine weather cannot be relied on until after the summer solstice; nor does bad weather set in until about the end of June. From September to Christmas may be called growing weather; from January to March steady ripening weather. As far as the experience of nearly six years extends, sufficient moisture for the growth of crops and vegetables may always

be relied on, and bad harvest weather is unknown. It is impossible to conceive a state of the seasons more favourable to agriculture. . . . . The climate has a very sensible influence on the productiveness of the soil; for even the cold clayey earths, which are found at a very trifling depth all over the hilly and undulating lands, become extremely productive after having been well turned over and exposed for some months to the action of the atmosphere. . . . . The great influence of the climate on the productiveness of inferior soils is very apparent. In the comparatively sandy belt of land which, varying in breadth from a few hundred yards to three or four miles, skirts the sea-shore between the bluffs of Paripari and the north-western extremity of the district of Wellington, potatoes, as well as other vegetables, are grown with great success by the natives. In the immediate vicinity of Waikanae, and several of the neighbouring native villages, the traveller is often surprised to find that even the careless agriculture of the natives can reap such excellent crops from what appear to be mere sandhills; and it seems difficult to explain the fact otherwise than as the effect of the genial climate, which is better perhaps than any other in the world calculated to encourage and promote the vigorous and healthy growth of animal as well as vegetable life." *

382. *Fertility of Crops attributed to the large Supply of Carbonic Acid Gas in the Air.*—According to the theory we have put forward in these pages, this remarkable effect of the atmosphere in rendering the poorer soils of New Zealand productive is probably due to the absorption of its large supply of carbonic acid gas. The effect described in the foregoing extract will be better appreciated by the cultivator of lands in the north hemisphere, when it is understood that no indigenous animal manure mingles with the soils of New Zealand, simply because there were no herbivorous or carnivorous mammals in these islands before the white man visited them. Since then the colonists have introduced sheep and cattle, but they had to sow European grasses, after extirpating the fern, to obtain proper

* 'Handbook for New Zealand,' issued by Canterbury Association.

pasturage for them. In doing so they found the soil and climate admirably adapted for every description of European grasses; and these may be seen growing in greater luxuriance upon the thin soils of the country than on the best-manured lands in Great Britain. This can only be attributed to an abundant natural supply of the elementary food of vegetables, imparted to the soil by the atmosphere, and cannot be the mere effect of a genial climate, which no doubt has a certain influence, but not sufficient to account for the extraordinary development of vegetation in New Zealand.

383. *Difference in Volume of Constituents Evidence that the Particles of the Air do not universally intermingle.*—The general inference to be drawn from the foregoing data is, that the atmosphere, in its circulation, does *not* mingle its gaseous constituents from pole to pole, as popularly understood, and as Captain Maury has endeavoured to show by the ingenious hypothesis already mentioned. It would appear that the tropical and equatorial belts of calms act as barriers to polar circulation, while they circumscribe the limits of the great aerial currents between them and the poles. In discussing the phenomena of the trade-winds, we ventured to suggest that each current of air circulated between the belts without crossing the equatorial zone of calms. On the same grounds we may conjecture that the westerly winds that prevail in the temperate zones rarely or ever mingle with the trade-winds, from which they are divided by the tropical belts of calms. This is especially observable in the west winds of the south temperate zone, which blow with as great steadiness and regularity from west to east as the south-east trade-winds themselves, if, indeed, they are not constant, more or less, in that direction. Master-mariners trading to Australia know this so well that they never attempt to make the return passage by way of the Cape of Good Hope, as they would encounter a head-wind and current, but avail themselves of its complete circle round the world, and sail homeward-bound by way of Cape Horn. In our long sea-voyages we have made this passage across the South Atlantic, the Indian Ocean, and the South Pacific, back

to the point of departure—thereby circumnavigating the globe between 36° and 56° S. lat., sailing before a constant westerly wind so strong and steady that the distance of 18,000 miles has been accomplished in 75 days by sailing vessels, making an average of 240 miles a-day. The testimony of Captain Maury on this point is even more conclusive, and is valuable in this instance as coming from the highest authority on the subject, who supports the polar circulation of the atmosphere.

384. *Maury's Account of the "brave West Winds" in the South Hemisphere.*—"My own observations," he states, "and the experience of mariners who are acting as observers in these researches touching sea and air, show that the westerly winds, which blow counter to the trades on the polar side of the tropical calms, are much more steady, strong, and constant in the southern than in the northern hemisphere. The former have won for themselves, among mariners, the name of the "brave west winds" of the extra tropical south. They are quite as constant from the west as in the North Atlantic the trades are from the east. Sailing with them to and from Australia, ships under canvass alone have attained a speed and accomplished runs which steam has never enabled any vessel to reach. In two months' time, and less, vessels have performed voyages of complete circumnavigation before these brave winds." And, again, he alludes to them in another passage as follows:—"To appreciate the force and volume of these polar-bound winds in the southern hemisphere, it is necessary that one should 'run them down' in that waste of waters beyond the parallel of 40° south, where 'the winds howl and the seas roar.' The billows there lift themselves up in long ridges with deep hollows between them. They run up high and fast, tossing their white caps aloft in the air, looking like the green hills of a rolling prairie capped with snow, and chasing each other in sport. Still their march is stately and their roll majestic. The scenery among them is grand, and the Australian-bound trader, after doubling the Cape of Good Hope, finds herself followed for weeks at a time by these magnificent rolling swells, and lashed by the 'brave west winds' furiously."

385. *Botanical Evidence in favour of our Theory conclusive as to the disparity in the Volume of the Carbonic Acid Gas in the North and South Aerial Hemispheres.*—It requires no profound knowledge to see that such a strong current of air, blowing almost perpetually from west to east in temperate latitudes, and circumscribed at its tropical boundary by a belt of calms, would prevent the mingling of the particles of air in the south with those in the north temperate zone, if indeed it does not prevent an intermingling of the air under the influence of the trade-winds. On the other hand, it requires a great deal of scientific faith to believe in the journey of Captain Maury's imaginary particle of air from one pole to the other, with such intricate ups and downs in its course across the calm-belts. But even he seems doubtful of his hypothesis as regards the crossing of the "brave west winds" through the southern calm-belt. Although he considers he has sufficient evidence to show that crossings take place in the north hemisphere and at the equator, he says, "But the circumstances going to show the crossing at the calms of Capricorn did not amount to evidence; the crossing was only inference drawn by analogy." Thus, according to the propounder of the polar theory of circulation, it is possible that the air in the south temperate zone may not cross the tropic, if evidence be found to rebut an "inference drawn by analogy." With becoming deference to the opinions of such an eminent authority as Captain Maury, we think that we have furnished botanical evidence which goes to prove that no such intermingling takes place, and that there is a disparity in the volumes of the atmospheric constituents in the two hemispheres, or at all events between their temperate regions. Moreover, instead of this difference being unsuited to the flora and fauna of one hemisphere conveyed to the other, we have seen how the flora of the north flourishes more luxuriantly in the south than in its own indigenous latitudes, and we shall now proceed to show how the fauna is affected, and especially how Europeans thrive physically under the hygeian influences of the Australian climate from atmospheric causes.

CHAPTER XVIII.

CONTRAST BETWEEN THE CLIMATES OF THE NORTH AND SOUTH HEMISPHERES.—CHINA.

Introductory remarks on the practical section of our theory, § 386.—Property of exhaling oxygen gas possessed by vegetation, 387.—Indications of an increased volume of oxygen in the Australian air, 388.—The evergreen vegetation of Australia exhales oxygen continuously, 389.—Properties of oxygen gas in supporting animal life, 390.—Probable disparity in volume of the oxygen in the north and south hemispheres, 391.—Climate and its effects upon the human constitution defined, 392.—China and Australia present the greatest contrasts in salubrity and insalubrity of climate, 393.—Vital statistics of China showing its insalubrity from excessive population, 394.—Prevalence of filth in China both in town and country, 395.—Great extent of land occupied by tombs of ancestors in China, 396.—Chinese coffins are made to last for generations, 397.—Reduction of oxygen in the air of China by the respiration of the people, 398.—Monsoon winds and geographical position in China prevent free circulation of air, 399.—Absence of forests in China and scarcity of large trees, 400.—Prevalence of virulent epidemic and endemic diseases in China, 401.—Dr Hobson's report upon the classes of diseases in Canton and Shanghai, 402.—Dr Henderson's remarks upon the climate of Shanghai and its environs, 403.—Great mortality during the summer at Shanghai, 404.—Suddenness of death and rapidity of corruption in China exemplified, 405.

386. *Introductory Remarks on the practical Section of our Theory.*—Perhaps discussing this question so minutely may appear to the reader useless, as it is a matter of small importance whether our theory be right or wrong. If it led to no other than some barren conclusion, we would abandon the inquiry at this stage and apologise for taking up the reader's time upon an apparently straw-splitting discussion. Apart,

however, from the interest of the question in a scientific point of view, our principal motive for entering further into it is to show that there are healing influences in the south aerial hemisphere capable of restoring afflicted humanity suffering from diseases (especially those of the respiratory organs) to a state of health which they never enjoyed in the north hemisphere. This, therefore, may be considered the practical section of our work, in which we shall endeavour to prove that our theory, however much it may be disputed, leads to some useful object in the end. Hitherto it would appear as if the learned denizens of the north hemisphere have considered that it included all the physical phenomena of the world, almost ignoring the disparities existing in the south hemisphere by considering it merely a counterpart of its antipodes, or only citing particular facts in illustration of some general question. There are exceptions to this class of limited philosophers, among whom we may mention the renowned Humboldt, who in his writings has pointed out the wonders of the south, in graphic and eloquent language, on the 'Views of Nature and the Sublime Phenomena of Creation' in the continent of South America. Humbly following in the footsteps of that great luminary of science, if we succeed in throwing any new light upon the physical phenomena of the south hemisphere, our fondest aspirations will be attained.

387. *Property of exhaling Oxygen Gas possessed by Vegetation.*—In the foregoing disquisition regarding the effects of vegetation on the constituents of the atmosphere, the principle exemplified has been that of *absorption*, or the extraction of a gaseous element from the air. We shall now proceed to examine an opposite property, wherein the air receives from vegetation a portion of its great vital constituent, oxygen gas, by *expiration*. "Plants, like animals, are therefore provided with a kind of respiration which, in the former, as in the latter, consists of two phenomena—inspiration and expiration. This function is very perceptible when we immerse the branch of a tree or a young plant in a glass bell filled with water, and expose it to the action of light. There is

then seen rising from its surface a great number of small bubbles, which are formed of a very pure air almost entirely composed of oxygen gas. On the other hand, let the experiment be made in a dark place, and the leaves will expire carbonic acid and nitrogen gas, but no oxygen. It must here be carefully remarked, that all the other parts of the vegetable which are not of a green colour, such as the roots, the bark, the flowers, and the fruits, when subjected to the same experiments, always exhale carbonic acid gas, but never oxygen. Consequently the expiration of oxygen gas does not depend solely upon the direct influence of the rays of light, but also upon the green colouring of the parts." *

388. *Indications of an increased Volume of Oxygen in the Australian Air.*—Now let us apply these well ascertained facts in vegetable physiology to the phenomena of foliage generally, as a generator of oxygen gas. Where the trees and shrubs are evergreen, and the sunshine is bright and most frequent throughout the year, it is logical to infer that a much larger proportion of oxygen must be given forth to the atmosphere than where the shrubs and trees are deciduous, and the sun's rays are frequently obscured by clouds and vapours. Such are the comparative characteristics of the vegetation and climatic conditions of the south and north temperate regions respectively. We have seen how the forests of New Zealand, Australia, South Africa, and South America are perpetually green with foliage; and it is equally demonstrable by meteorological registers kept in these regions, that abundance of sunshine is the rule at all seasons of the year. Nothing is more striking to the observant traveller in south temperate regions than the remarkable clearness of the sky, and its cloudless aspect, for days and sometimes weeks together. In Australia we have experienced these continuous days of glowing sunshine so as to pall upon us, and we have felt a refreshing relief at the sight of a cloud portending rain in the heavens. Still this glowing unobstructed light and heat from the sun was never oppressive to the

* Rhind's 'Vegetable Kingdom.'

senses. On the contrary, our animal spirits were invigorated; and in riding through the uncultivated wilderness of that sunny south land, we have felt a buoyancy, an exhilaration, amounting to a degree of intoxication of mere animal existence, that we never have experienced in the north hemisphere, and which we can only compare to a mild degree of the sensation experienced from inhaling nitrous oxide gas, commonly known as "laughing gas" from its agreeable effects upon the system. No doubt this arises in some measure from the dryness of the atmosphere; in tropical climates we find that an equal degree of heat with humidity creates prostration of the animal spirits. Nevertheless we are of opinion that the presence of a greater volume of oxygen in the air inhaled has something to do with it. Let us now inquire what data exist to support such a hypothesis.

389. *The Evergreen Vegetation of Australia exhales Oxygen continuously.*—We have already described the evergreen aspect of the Australian trees, and the manner in which the leaves of gum-trees, the *eucalypti* of botanists, are placed upon the leaf-stalks, with their edges upwards instead of horizontally, as in deciduous trees generally speaking. This disposition of leaves, according to the principles laid down in vegetable physiology, as already given, is admirably adapted for the greatest possible volume of oxygen gas being evolved from their superficies on both sides. It has been further ascertained by experiment that leaves do not exhale oxygen during the night, nor in the dark umbrageous shade of a forest during the day, or only in a small degree compared with those exposed to the sunshine. Thus in forests where umbrageous trees, having a maximum of leafage—such as the sycamore, chestnut, and elm—predominate, the more they contribute to creating the cooling shade by the density of their foliage, the less is their utility as vegetable laboratories in producing oxygen gas. On the other hand, the peculiar disposition of the gum-tree leaves presents a minimum surface of obstruction to the light reaching the lower branches, while the leaves on the upper branches receive the direct rays of

the sun during a sunny day on each side, forenoon and afternoon, with all their intensity. Consequently, although the foliage of the Australian forests is small compared with the broad-leaved trees of our English woods, yet the superficies is doubled in performing this vital function of their organisation. And when we take into consideration the phenomenon of perennial foliage in the one case flourishing throughout the year, from generation to generation, while that of the other deserts the branches for half the year, we may conclude that the Australian trees surpass them in the volume of oxygen gas they generate. Also, as they never cease to evolve their daily supply of this vital constituent for the healthy support of animal life, the atmosphere is more equably charged with it in the south temperate zone than in the north, where, during the six months' denudation of foliage, there is a cessation in the evolvement of oxygen gas from this source, while its consumption by lung-respiring animals goes on all the same; and in civilised countries a greater consumption takes place in supporting combustion. Hence we may reasonably infer that during winter in the north temperate zone there is probably a slight diminution in the volume of oxygen compared with the quantity in the atmosphere during the summer, especially in the "leafy month of June," when the woods and forests present their greenest and densest foliage to the sun's rays.

390. *Properties of Oxygen Gas in supporting Animal Life.*—In this age of popular scientific literature and institutions for the advancement of science, almost every intelligent person knows that oxygen gas is the chief life-giving element of the air we breathe. As carbon is the great supporter of vegetable life, so is oxygen the pabulum of animal existence. Experimentalists have satisfactorily demonstrated that no animal with lungs "can live in an atmosphere which does not contain a certain portion of uncombined oxygen. Pure oxygen is too highly stimulating for animal existence; and it accordingly appears that it is owing to the proportion in which it is combined with nitrogen, in our atmosphere, that

it becomes precisely adapted to the support of life."* In the process of respiration it is more or less consumed by absorption into the system. "The great end which appears to be answered by respiration is the removal of carbon, in the form of *carbonic acid*, from venous blood. This gas is accordingly found in the air which is expired from the lungs; and the blood, having lost its carbonic acid, at the same time loses its dingy hue, and acquires, through the inhalation of oxygen from the air, the florid red which characterises arterial blood. Respiration alternates with inspiration, which takes place about twenty-six times in a minute, thirteen cubic inches of air being the average quantity taken in at each inspiration."† Of this volume, one-fifth, or say two and a half cubic inches, is oxygen—a quantity which the average human being withdraws from the atmosphere every two or three seconds, and thereby reduces its life-supporting properties accordingly. The effects of this exhaustion of the vital element in respiration are constantly recurring in ill-ventilated rooms, where large numbers of people assemble, and its fatal results are recorded in the terrible sufferings and death of the prisoners in the Black-hole at Calcutta.

391. *Probable Disparity in Volume of the Oxygen in the North and South Hemispheres.*—Seeing that the inhalation of pure oxygen into the respiratory organs creates an extraordinary excitement of the animal spirits, and that the reduction of this gas produces complete prostration of the vital energies, we may infer that what is seen so vividly at these extremes is observable in lesser degree towards that point where the healthiest combination exists. On the one hand, where the volume of oxygen is below the standard, the individual breathes with difficulty, languor follows, and if the respiratory organs be weak, bronchitis and pulmonary complaints ensue. On the other hand, when the proportion is at or slightly above the standard, the lungs have vigorous action in purifying the blood, giving strength to all the organs of respiration, and protecting them from disease. Furthermore,

* Ogilvie, 'Imperial Dictionary.' † Ibid., Art. "Respiration

where disease may have set in, the removal of the patient from the one atmospheric condition to the other will cause its progress to be arrested, if not cured altogether. Such are the general phenomena experienced by persons living in the temperate regions of the two hemispheres, which we attribute to a decrease of this vital constituent in the north, while its original proportion is maintained in the south. It may be advanced, in opposition to such a hypothesis, that the consumption of oxygen by human beings and air-respiring animals is so infinitesimal compared with the inexhaustible supply in the atmosphere, that it can have no effect in the diminution of its volume. To this we reply, that as there are no direct analyses to support either argument, we may inquire what indirect data can be found to sustain the views herein expressed; and as we have pointed out certain negative evidences of a diminution of carbonic acid gas in the north aerial hemisphere, so may we find indications of the oxygen gas having lessened in volume, while the south retains its primary proportions.

392. *Climate and its Effects upon the Human Constitution defined.*—Pursuing our inquiries in this direction, we are naturally led into the consideration of that important branch of atmospheric phenomena called Climate, which is determined by Humboldt as follows:—"The term *climate*, taken in its most general sense, indicates all the changes in the atmosphere which sensibly affect our organs, as temperature, humidity, variations in barometrical pressure, the calm state of the air or the action of opposite winds, the amount of electric tension, the purity of the atmosphere or its admixture with more or less noxious exhalations, and, finally, the degree of ordinary transparency and clearness of the sky, which is not only important with respect to the increased radiation from the earth, the organic development of plants, and the ripening of fruits, but also with reference to its influence on the feelings and mental condition of men." To these general conditions we venture to add: And for man to benefit by climate in the highest degree it is necessary that the air he breathes

should contain its full proportion of oxygen gas; where that is deficient, we contend that the most robust individual cannot thoroughly enjoy all the changes in the atmosphere that sensibly affect his organs.

393. *China and Australia present the greatest Contrasts in Salubrity and Insalubrity of Climate.*—In looking over the map of the north hemisphere for a region to illustrate in its most vivid manner the effects of population on climate, we cannot confine our observations to the limited area of the British Isles, or even the continent of Europe, if we have to observe the great operations of nature in her atmospheric laboratory. It is in Asia, especially in the far East, where the empire of China supports one-third of the human race, that we find examples of the extreme of malaria and disease, caused by a low condition of the vital constituents of the atmosphere in the northern zone. On the other hand, we shall select among the regions within the influence of the south temperate zone the island-continent of Australia, as the sparsest-peopled country on the face of the earth, revelling in the enjoyment of the healthiest climate, where malaria and endemic diseases are almost unknown. A greater contrast between the salubrity and general climatic conditions of two regions is not to be found in the world than those of China and Australia, each representing in the highest degree the differences of geographical and atmospherical phenomena in their respective hemispheres. Having dwelt in both of these countries for many years, and travelled thousands of miles through them, carefully observing their physical geography, and especially the effects of climate upon the indigenous inhabitants and European residents, we shall give the result of our experiences and observations impartially, with a view to open up further investigation on the important study of climatology in the southern hemisphere. Regarding the accumulation of facts on this subject in the northern hemisphere, from colonisation and long residence, Humboldt records his opinion as follows:—"The progress of climatology has been remarkably favoured by the extension of European civilisation to two opposite

coasts,—by its transmission from our western shores to a continent bounded on the east by the Atlantic Ocean. When, after the ephemeral colonisation from Iceland and Greenland, the British laid the foundation of the first permanent settlements on the shores of the United States of America, the emigrants were astonished to find themselves exposed to an intensity of winter cold far exceeding that which prevailed in Italy, France, and Scotland, situated in corresponding parallels of latitude." In like manner the colonisation of Australia has enlarged our views of climatology, but in a more genial sense, as a region that may be considered the grand sanatarium of the world.

394. *Vital Statistics of China, showing its Insalubrity from Excessive Population.*—Of the two regions thus selected we shall first direct our attention to China, as the most ancient existing seat of civilisation, where the most populous branch of the human race, during more than a thousand generations, has altered the face of the country, and materially changed its climatic relations. In doing so it is not necessary to enter into details that would involve the consideration of the climate pertaining to each province or parallel of latitude. Our object will be attained in taking a general view of its physical geography and population, with an example of the climate in middle latitudes. In the nineteen provinces now comprising China Proper the estimated area of land, including lakes and rivers, is 1,297,999 square miles, or about one-third of the superficies of Europe; and the population, according to the latest computation in 1842, 414,686,994. At this ratio the continent and islands of Europe, were they as densely populated as China, would contain 1200 millions of persons, or as many as the whole human race existing at present; whereas, by the census drawn up in 1851, the inhabitants of this section of the globe do not count, in round numbers, more than 260 millions. It will be readily conceived that this enormous population, crowded within a limited territory compared with the average of European nations, must constitute a pestilential overcrowding of the land. Such is the case, and the effects

are aggravated by the intense heat and humidity in the summer, the filthy state of the towns and cities, the practice of manuring the lands with human ordure, and, generally, the dirty habits of the people themselves. To these existing causes we may add one that has assisted materially from time immemorial in vitiating the atmosphere of China—namely, the remains of a thousand generations buried in the land.

395. *Prevalence of Filth in China, both in Town and Country.*—The Chinese denominate their country *Tien-chaou*, a term signifying "Heavenly Dynasty," or, more properly rendered into English idiom, "The Celestial Empire." This high-sounding title naturally begets the idea that the physical condition of the country and the inhabitants is everything that is pure and unsophisticated. In reality, nothing can be further from such a pleasing impression. Man in that region proves himself to be the dirtiest of animals, and his general habits and pursuits are of "the earth earthy." The cities and their environs, the countless towns and villages, and the extensive cultivated lands, are so strewed and impregnated with the remains of the dead and the rejectamenta of the living, that China Proper may be designated a vast dunghill and graveyard, befouling and poisoning its sultry clime. It is a fact too patent to the olfactory nerves of all travellers and foreign residents at the treaty ports, that the practice of manuring the lands with human ordure in a liquid form is universal. Few works on China do little more than casually allude to this agricultural practice, on account of the unpleasantness of the subject. But we may be excused from such delicacy, as the fact is material in showing the low sanitary condition of the country. The habits of the Chinese in this respect are like those of the beasts of the field or the dogs of a city. Wherever or whenever inclination seizes them, irrespective of what we call decency, the common people answer the calls of nature, and there are no government or municipal regulations to prevent them doing so, except in the foreign settlements. In the country, where one would expect to find fresh air among the fields, a noisome stench prevails; the

narrow paths are strewed with excrement, and large vases of stoneware are sunk in the ground at convenient places for the use of passers-by. During the spring, when the rice-fields begin to delight the eye with their bright-green aspect, the sense of smell is disgusted by the effluvia arising from the liquid manure that covers the soil. It is even worse at some parts of the narrow lanes that constitute the streets of Chinese towns. The filthiest offal is gathered in heaps at the sides of these thoroughfares, and privies are open to public gaze, where the stench is so abominable that the visitors before entering them take the precaution to stuff their nostrils, though already inured to the national effluvia. Almost every town and city is surrounded by a ditch or intersected with canals, into which the drainage of the densely-packed houses flows, turning them into great receptacles of corruption, that swelter at low water under the torrid summer sun. Even the numerous and large lakes and rivers that constitute the chief highways of commerce, contain an unusual amount of putrid animal and vegetable matter, so that it is necessary to purify the water with alum before it can be used by foreigners for drinking or culinary purposes. Such is the invariable practice at Shanghai, even amongst the Chinese. In the Wong-poo river that flows past that city, the proportion of putrescent matter is so large, that in the height of summer the water assumes a gelatinous consistence, which is felt by bathers, who seek in vain for a refreshing plunge into the fetid stream or a bath filled with its offensive water. As there are comparatively few animals in that agricultural country, almost the whole of this corruption arises from the presence of the human race forming such dense centres of population.

396. *Great Extent of Land occupied by Tombs of Ancestors in China.*—Not only does the present generation spread their rejectamenta broadcast over the surface of the land, to the detriment of its sanitary condition, but the remains of past generations everywhere impregnate with their corruption the soil that yields the staple crops. Besides the cemeteries within walled cities, and the burial-places in the suburbs,

every farm in China has a portion of the land occupied by the tombs of the farmer's ancestors, for many generations back. And as the "worship of ancestors" is part of the national religion, these tombs are held sacred as shrines for the devotees to worship at and present sacrificial offerings. Hence they are rarely disturbed for centuries; and if so, the bones are carefully preserved in stoneware jars. It would be an interesting statistical question to know what extent of land is covered with tombs and used as graves in China. In the absence of such we may make an approximate calculation from our own knowledge, and that of intelligent natives and foreign travellers whom we have questioned on the subject. Of the cultivated lands it is no exaggeration to state that probably not less than three per cent of the area is covered with ancestral tombs, thereby withdrawing from profitable culture an immense tract of available land; while the cemeteries and tombs everywhere built among the rocky and waste lands may amount to two per cent. So that in all probability not less than one-twentieth part of this extensive country is held as receptacles for the dead, whose remains are interred in strong coffins, most of them covered by brick tombs. Within these vaults are buried probably not less than a hundred thousand millions of human beings in various stages of corruption, each retaining in a solid form some portion of atmospheric vital constituents necessary for the healthy conservation of the living generation.

397. *Chinese Coffins are made to last for Generations.*—The business of coffin-making in China is of much more importance than in any European nation, and the article itself is a more substantial, and sometimes ornamental, piece of furniture than any household piece of cabinet-work. They are made of the hardest or toughest timber that can be got, from two to three inches thick, and so closely joined that no liquid matter can flow through the seams, while a strong cement is spread on the edges of the lid when nailed down, so that a Chinese coffin is almost hermetically sealed, in order to prevent the escape of effluvia during the long period

between death and interment. Quicklime is also placed in the coffin to neutralise the decomposing gases. In ordinary cases the funeral does not take place for thirty or forty days; and where the deceased dies at a distance from his native district, the remains are stored in houses for the purpose for many months. The number of these buildings in Canton is considerable. On the decease of persons who have no burial-place in or near the city, their remains are placed in coffins, closed hermetically, or nearly so, and are then carried out and deposited in these houses, from whence, after months or years, the mouldering body is borne away to seek affinity with its ancestral dust. Under these circumstances it will be seen that a coffin is an article of no small importance in the social economy of the Chinese; and it sometimes becomes an expensive luxury where the deceased has left means and instructions for one of superior wood and workmanship to be made. We have seen one, in which the remains of a wealthy silk-merchant were interred, that cost a sum equivalent to one hundred pounds sterling. In fact, a finely-made and substantial coffin is considered by a Chinaman as an important matter while alive; so that it is not an uncommon thing to see them in the houses of the wealthy as a prudent provision for, or probably to remind them of, death. As the ancient Egyptians hung up a skeleton at their banquets for that purpose, so do the modern Chinese display their coffins during an entertainment, or at all events have them in an adjacent apartment. Cases are common of the dying patient having his coffin brought to his bedside, who gives up the ghost with greater serenity of mind at the prospect of having a substantial tenement among the tombs of his ancestors.

398. *Reduction of Oxygen in the Air of China by the Respiration of the People.*—While the rejectamenta and remains of this multitudinous nation contribute largely to the malarious exhalations from the land and water, the atmosphere is also largely deprived of its oxygenous vitality by respiration—more so than in any other country in the world; and there is, perhaps, no other habitable region so destitute of foliage

for generating oxygen gas. We have already referred to the consumption of this vital constituent in the process of respiration, together with the unhealthy effects arising from breathing air thus vitiated in crowded assemblies. May we not apply this experience of sanitary laws on a small scale to atmospheric volumes of a greater magnitude, such as are found in the badly-ventilated valleys of the Alps, and include even an extensive region like China as under their influence, where it is densely thronged by human beings, and Europe with its respiring animals? If the principle of oxygenous exhaustion is deleterious to life in such cases as crowded rooms, it is strictly logical to conclude that the same causes will produce similar results on the greatest scale, not excepting the northern aerial hemisphere itself, where nine-tenths of the whole human race are congregated. Here it may be said that, south of the sixtieth parallel of latitude, a thousand millions of human beings and myriads of respiring animals inhale the air, consuming its oxygenous constituent every moment of the minute, every minute of the hour, every hour of the day, every day of the year, every year of a century, and so on, *ad infinitum*. May not this inconceivable respiration of the organic world—this continual demand upon the oxygenous food of the atmosphere—diminish its vital elements generally? May not the four hundred million pairs of lungs in China exhaust the air in that region of its oxygen to a tangible extent, just as four thousand pairs of lungs may do proportionately within a confined area?

399. *Monsoon Winds and Geographical Position in China prevent free Circulation of Air.*—It may be advanced that the analogy drawn is not applicable, inasmuch as China is an immense territory open to the Pacific Ocean, from whence abundant supplies of fresh air and oxygen come to renovate the vitiated atmosphere. This, apparently, would be the result under different atmospheric conditions, but the prevalent monsoon winds, and the geographical conformation of the country, prevent a general free circulation of the air. By reference to any ordinary map of China it will be seen that,

although the country is open to the east and south along its seaboard of 3350 miles, yet on its western and northern boundaries it is walled in, as it were, by the stupendous mountain chains and table-lands of Tibet and Tartary. This geographical conformation prevents the blowing of any constant west or north-westerly wind, so as to sweep across its extensive lowlands towards the east, and causes the monsoon winds to blow alternately from the south-west and north-east six months at a time during the year. At the change of the monsoon there are calms and variable winds, without any strong easterly breezes from the Pacific, excepting the dreaded typhoons, which sweep along the coast with terrible severity, without, however, disturbing the inland monsoon winds, on account of their rotatory motion and limited sphere of action. Thus in China the currents of air are carried to and fro across the country, blowing from the south-west during the warm half of the year, and from the north-east during the cold half; and as the ebb and flow of a river conveys up and down the stream its deleterious particles, so may we suppose this great annual atmospherical tide to act, carrying backwards and forwards the air vitiated by the rejectamenta of the densest population on the earth, who must have sensibly diminished its vital oxygenous properties, without receiving that supply of fresh air which other regions, more advantageously situated, obtain from the atmosphere.

400. *Absence of Forests in China, and Scarcity of Large Trees.*—Besides the theocratic appellation of "Celestial Empire," the Chinese name their country *Chung Hwa Kwo*, which signifies "Central Flowery Land." As we have seen how little China deserves its heavenly title, so may we conclude that where such pestiferous odours prevail over monotonous cultivated fields, there can be but a small portion of the land covered with growing flowers and exhaling sweet perfumes. It must be said, however, that where gardens are to be found the flowers are of exquisite beauty; and we can easily imagine that before China was so cut up by culture for food the indigenous plants were abundant, and

suggested this appellation. All this, however, is altered, and the native flowers are more rarely to be seen there than they are in the gardens of England. But that which strikes the observant traveller most regarding the vegetation of China, is the absence of forests and the rarity of clumps of trees of large growth. This cannot be natural, for the rapidity of vegetable growth is marvellous on the cultivated lands, and the comparatively few trees and shrubs that are seen display great luxuriance in their foliage. According to the ancient history of the country, its aboriginal inhabitants dwelt in forests and caves, where wild animals disputed its occupation with them. With the advent of Chinese civilisation these forests have almost disappeared; and the timber trees that formerly covered the mountains and valleys have been used for building purposes and fuel without new plantations being raised in their stead, except upon a very limited scale. Hence in China there are few leafy trees spreading their foliage in the sun's rays to generate oxygen gas, which is so largely consumed by the dense population; while its diminished volume is supplanted by deleterious gases that create all sorts of diseases, and render the climate generally one of the most unhealthy in the world, especially for European constitutions.

401. *Prevalence of Virulent Epidemic and Endemic Diseases in China.*—To enumerate the various classes of disease that afflict the Chinese would be simply to quote the whole list given in a medical dictionary. Perhaps there is not an ailment that is known amongst Western races but has its counterpart among that peculiar people; so that, as far as the "ills our flesh is heir to" are concerned, they are of the same original stock. There are data for concluding that most of the plagues and epidemics that scourge the human race from age to age have their origin in this great hotbed of disease. That mysterious morbid malady, cholera, which appears as an epidemic in Europe, is endemic in China, and of the most virulent Asiatic type. Scientific physicians trace its approach always from the east, through the agency

of electric currents, which in some unknown manner rule its deadly march, like the influence of the great tidal wave rolling to the west; and thus it may be brought from that *ultima thule* of the far East to these western shores. Small-pox, which is of very ancient origin in China, in all probability originated there, where diseases of that character are the most dreaded by the people. On this point, and others illustrative of diseases in China, Dr Hobson, late of Shanghai, who had great experience in hospital practice among the natives as a medical missionary, furnishes the following comparison of the various classes of diseases in the tropical and temperate latitudes, where, contrary to general results, the latter region is the most unhealthy:—

402. *Dr Hobson's Report upon the Classes of Disease in Canton and Shanghai.*—"On comparing diseases and climate in this part of China, lat. 32°, with Canton, lat. 22°, there are several differences which cannot fail to be observed, and will justify, I believe, the following conclusions: 1. That a far larger proportion of diseases among the inhabitants of this vast plain—where irrigation is greater than in any other part—are of an intermittent or periodic character arising from malaria, and must be treated by quinine and other anti-periodic medicines. Canton and Macao are nearly entirely free from marsh effluvia, and hence intermittent fevers, neuralgia, dysentery, and nervous depression, are much less common in these parts than here. 2. That inflammatory effects of the breathing organs are far more frequent in this part of China; hooping-cough and croup are unknown, and acute bronchitis, pleurisy, and pneumonia are very rarely seen in the south of China. I observe no difference as regards sanguineous discharges, dropsical effusions, and pulmonary consumption. 3. This climate is more trying to young children, especially during the time of teething. It is also unsuitable, from its sudden alternations of temperature and increased cold and dampness, to persons of weak lungs or of a rheumatic diathesis. It is also disagreeable and enervating at first to residents who have been accus-

tomed to the tropics, especially to those of a nervous excitable temperament, or liable to intermittents. 4. Cutaneous diseases among the natives here are much more frequent and severe, owing to want of frequent ablution, and from wearing the same wadded clothes for months together, and even for successive years, during the winter months, without washing the under garments. Scrofulous enlargement of the glands and leprosy are, however, far more common at Canton than at Shanghai, probably from the excess of heat. Diseases that are most dreaded are the small-pox in the spring months, cholera and infectious fevers in the hot months. Diarrhœa and dysentery occur at all seasons of the year, but more in the summer than the autumn. Cachectic and anœmic diseases seem common everywhere, arising, no doubt, from insufficient food and foul air combined. Tumours and calculous diseases are of greater frequency in the south; but though the climate there is more relaxing, the vigour and activity of the native mind are superior to what is usually met with in this part of China. I attribute this difference—which has been remarked by many—chiefly to the morbific influence of malaria, which contaminates the atmosphere in this rich and extensive plain. The apathy and timidity of the Keang-soo people are proverbial."

403. *Dr Henderson's Remarks upon the Climate of Shanghai and its Environs.*—Regarding the climatic conditions of the province of Keang-soo, and their relations to the atmosphere as affecting the human constitution, we shall quote the remarks of another authority, Dr Henderson, who succeeded Dr Hobson as physician in charge of the Chinese Hospital at Shanghai; and who, like his predecessor, succumbed, while yet in the vigour of life, to the deadly influences of the climate. "During the sudden changes of temperature," he says, "which at certain seasons occur in Shanghai, bronchial catarrh is exceedingly common, and in elderly people passes into a chronic state, and in almost every respect simulates consumption, and will pass to this disease unless the chest is carefully examined, when the disease is found entirely confined to

the bronchial tubes, the lungs being perfectly sound. The climate of Shanghai is essentially humid, and during the hot months of July and August the atmosphere approaches close to and often reaches the point of saturation; the air is much rarified, and contains less oxygen in a given bulk than when it is cold and dry, while respiration is shallow and more slowly performed. Thus the blood is less perfectly oxydised, and contains too little oxygen to stimulate the heart, blood-vessels, and nerves, and the individual is predisposed to low types of disease of a periodic character. During the hot months, also, the hygrometric state of the atmosphere is such, on certain days after heavy rains in Shanghai, that instead of watery vapour being exhaled from the lungs at the rate of one ounce per hour, as in tolerably dry states of the atmosphere, I am strongly inclined to believe that pulmonary exhalation is all but arrested, and the functions of the lungs reversed, have assumed for the time the function of absorption. Fluid passes off by the skin in two ways—namely, by evaporation, which is essentially a physical process; and also in the form of perspiration, a vital process of transudation. Now, when the air is saturated with moisture and its temperature equal to that of the body, the vital process of transudation will only be carried on, the physical process of insensible evaporation having for a time ceased. The above conditions, however, are not common, and can only take place when the temperature of the air is equal to that of the body, and saturated with vapour. Under any circumstances, however, free evaporation from the body will be impeded, or modified, according to the amount of moisture in the air, and so will the feeling of languor and oppression be greater or less according to the state of the atmosphere, whether it is still or in free motion; and hence the advantage and utility of *punkas* and thorough draughts, as these change rapidly the particles of hot moist air, which retard evaporation if left to remain in contact with the skin." From our own experience, the intensely humid state of the air at these times is such that mere animal existence, even to a healthy person, is positively

painful. You feel as if your body was wrapped in an atmospherical poultice, which draws all the deleterious particles in the blood to the surface, and the skin breaks out with prickly heat (*Lichen tropicus*), more or less varied with a crop of boils. On consulting your physician, he pronounces these eruptions as a healthy indication of your constitution, otherwise they would have broken out internally, producing some virulent disease. This is for the time reassuring, but it impresses one with uncomfortable forebodings of suffering and death in the unhealthy climate of China.

404. *Great Mortality during Summer at Shanghai.*—During our residence in Shanghai an unusually hot and sickly summer occurred—when all the morbid influences alluded to existed in their worst form, and consequently disease stalked abroad like a gaunt spectre, destroying the foreigners as well as the natives with an unsparing hand. So great was the mortality, and the deaths so sudden, that it was like being on a field of battle, when every moment a dart from the "King of Terrors" might strike any one, irrespective of age, as the strong man is laid low by the bullet of his enemy. Not only did the less vigorous constitution rapidly collapse under the blue agonies of Asiatic cholera, but those of a robust sanguineous temperament were struck down by heat-apoplexy as if they had been shot. We remember going on board a transport to bid adieu to the officers of the gallant 31st Regiment of infantry on their departure for England, after suffering decimation from the climate of China, when three privates were thus attacked. Fortunately there was ice at hand and skilful surgeons to apply it with success, and they recovered; but had they been on the march, where ice was not at hand, they could not have survived many minutes.

405. *Suddenness of Death and rapidity of Corruption in China exemplified.*—Not so fortunate was the case of a hale vigorous civilian, whose acquaintance we made at Shanghai. He had come from Tien-tsin, where the climate is not so deadly, as it is less humid. Fond of exercise, we observed

that he used to take what he called his "constitutional" in the morning, which he was warned against on account of the treacherous climate. But he did not seem to take much heed of our warnings, and continued his morning walks. One day at breakfast he complained of headache, and said he would lie down in his bed-room for a little. At noon a servant went to call him, when he was found dead in bed; and though the body was quite warm, even to fever heat, the doctor attending him could not restore the smallest sign of animation. In the evening we saw the body and felt the hands, which were still warm, and it was evident that putrifaction had set in with great rapidity. Such was the case, for about midnight the remains were placed in a coffin for immediate interment; and as the undertaker was closing the lid, the body burst its cerements and filled the coffin with noxious matter, which emitted a most horrible effluvium.

CHAPTER XIX.

CONTRAST BETWEEN THE CLIMATES OF THE NORTH AND SOUTH HEMISPHERES.—AUSTRALIA.

Geographical features of Australia admit of general free circulation of air, § 406. Native inhabitants and animals few and innocuous, 407.—Contrast between its sparsely-populated lands and those of China, 408.—Presence of the European colonists has introduced insalubrity into the towns, 409. Absence of malaria on its marshy lands attributed to deodorisation by carbonic acid gas in the air, 410.—Effects of carbonic acid gas on the human constitution by experiment, 411.—Carbonic acid recommended as a medicament by Dr Le Play, 412.—Healing effects of carbonic vapours in gasworks, 413.—Tetrachloride of carbon a valuable anæsthetic, 414.—Carbon in a solid, liquid, or gaseous form not poisonous, 415.—The climate of Australia considered by physicians as curative of pulmonary diseases, 416.—Dr Bird's experiences of its climate as a curative agent in consumption, 417.—In course of time it may become the grand sanatorium of the world, 418.—Transportation to Australia formerly a premium to criminals, 419.—Remarkable effects of the climate on the fecundity of European females, 420.—Longevity and fatal diseases of short duration in Australia, 421.—Its climatic influence in checking the spread of epidemics, 422.—Salubrity of Melbourne, Sydney, and Adelaide under exceptional conditions, 423.—The salubrious climate admits of sleeping out in the open air with impunity, 424.—Experiences in the moist climate of New Zealand indicate its salubrity, 425.—Military medical reports exhibit low rates of mortality and disease among the troops, 426.—High degree of health enjoyed by the New Zealand colonists, 427.—Dr Dieffenbach's remarks upon the absence of endemic diseases and the salubrity of climate, 428.—Hints for a new system of medical practice by *aeropathy*, 429.—Scope for improving the science of medical practice, 430.—Professor Simpson's address to the graduates of Edinburgh University, 431.

406. *Geographical Features of Australia admit of a general free Circulation of Air.*—Let us now compare the physical features and climatology of Australia with those of China,

or, what will be more appropriate, the eastern half of the former, as more closely approximating in area and latitudinal limits to the latter. Moreover, it is the section of the south island-continent of which we have the most correct geographical knowledge, and where the country is fairly populated, while the western division is comparatively an uninhabited wilderness. The entire superficies of Australia is computed at 2,690,810 square miles, so that half its area is something over that of China Proper. A glance at the ordinary map of the eastern hemisphere will show the general contour of these two regions, each possessing an extensive seaboard washed by the waves of the Pacific Ocean, and both under the influence of tropical and temperate latitudes, but on opposite sides of the equator. At this point their geographical analogy ends; for although a mountain-chain extends from south to north, parallel with the eastern seaboard, yet it cannot compare with the mountain-chains and table-lands of Tibet and Tartary, that obstruct the west winds in China. To the westward of the Australian Cordillera a level region extends through the interior nearly to the coast washed by the waves of the Indian Ocean; while the south is open to the Southern Ocean, without any land as far as the antarctic circle. In no part of Australia is there a mountain elevated above the line of perpetual snow, and nowhere are ranges of mountains or valleys so situated as to confine the currents of air from all points of the compass. Hence the general character of the Australian winds is their variableness. It is true that on the tropical waters of Australia monsoon and trade-winds blow, but they rarely penetrate far into the interior, while the "brave west winds," described by Captain Maury, in the south temperate zone sweep across the country during the greater part of the year. The geographical features of Australia, therefore, are not calculated to confine the atmosphere into periodical winds, as in China, but to afford a general free circulation at all times of the year.

407. *Native Inhabitants and Animals few and innocuous.*

—We have seen that the Chinese are computed at one-third of the whole human race—which is calculated in round numbers at twelve hundred millions—and that they occupy a territory less than the area of eastern Australia, where the native population is not equal to that of an ordinary English county. While the one region contains a vast series of centres of population more dense than anywhere in Europe, who have exhausted the health-giving elements of the air, earth, and water, the other was, until recently, an immense wilderness, tenanted by a few tribes of savages, whose poverty-stricken condition and nomad life rendered their presence less productive of noxious exhalations than the few wild animals inhabiting it. "The history of this race is comprised within a small compass. Records they have none, and their traditions are as evanescent as their dwellings; and like summer fires, which sweep every vestige of these rude structures from the face of the earth, so their history is buried in oblivion with each succeeding generation. No evidences of tilling the ground, planting, sowing seed, and reaping the harvest, have been seen by travellers among them. They do not trade or barter; neither do they sell, buy, or exchange land, and on no spot is a permanent village established. Consequently the rejectamenta of such a sparsely-scattered population have no effect in creating malaria. An approximate census taken in 1853 returned their numbers in eastern Australia at 210,000; and from their known rate of decrease within the colonial settlements, at present it is considerably less." *

408. *Contrast between its sparsely-populated Lands and those of China.*—Since the colonisation of Australia by the British, the usual effects of civilised communities forming centres of population are beginning to appear, but not sufficiently to have any marked result upon the general sanitary condition of the country. Still, where the cities and large towns exist, these localities are not so healthy as formerly, when the population was less; and fevers occur which, at the

* Art. "Australia," 'Encyclopædia Britannica.' By S. Mossman.

early periods of colonies, were unknown. Of the colonial population there are now about one million and a half persons, who have introduced and bred about forty millions of live stock, as assisting to vitiate the atmosphere. But what are these to the immense extent of country they roam over, or the widely-scattered towns and villages, compared with what exists in China? It is in this respect that the traveller in both countries is impressed with the contrast between a densely and a thinly populated region. In our travels we have ridden for hundreds—nay, thousands of miles through the "bush" of Australia—as the colonists term the unsettled and rural districts—and sometimes for days we have not met a human being, not even one of the aborigines. There population is the exception, and extent of territory the rule, where in its pristine state the land is in great part clothed with indigenous grasses, that wave in the breeze like fields of corn, and picturesque park-like forests invite the settler to erect his homestead, and sit under his own "vine and fig-tree," breathing the most salubrious atmosphere in the world. On the other hand, in China, population is the rule and land the exception; for the inhabitants find it insufficient for their increase, and hence about one-tenth, or forty millions, have their habitations and employment on the water. We have travelled through parts of one of the central provinces where the country was barren and rocky, with scarcely a tree or shrub to be seen by the wayside, and we have said to ourselves, "Here surely there will be some solitude from the overwhelming presence of the people." But no! Scarcely had we got to the hill-tracks than we found them crowded by an increasing stream of pedestrians carrying packages of tea and native produce towards the outports, and merchandise to the interior. It is only when the country is disturbed and desolated by bands of rebels or banditti that the population disappears from any district. But no sooner are these dispersed than the inhabitants return and industriously set to work and restore their dwellings, or renew the cultivation of their farms, so that in a short time the temporary solitude

of such localities is broken up by the noise and bustle of a dense population.

409. *Presence of the European Colonists has introduced Insalubrity into the Towns.*—It is not necessary to go into any detail of the population statistics of Australia in illustration of the infinitesimal influence the presence of civilised man has upon vitiating the atmosphere of that extensive region, from rejectamenta, graves, and other corruptions of humanity. And where malaria has arisen in the large cities from want of drainage and insufficient water-supply, these defects are being remedied by the authorities upon the most improved systems of Europe. It would be well also that the several governments of the Australian colonies adopted a system of prevention as well as cure in maintaining the salubrity of the climate and the fertility of the soil. We allude to the wholesale destruction of the trees in the environs of cities and other centres of population without providing for the future by planting saplings. We have already demonstrated, according to the experiments of learned chemists and botanists, the fact of green foliage generating oxygen in the sunlight, and pointed out the evergreen trees of Australia as peculiarly adapted to perform that function to the best advantage. Besides this delicate property, it is well known that trees protect the fertility of the soil where it is not cultivated, and hence their preservation or reproduction on waste lands is of importance in that dry climate. We regret to state that some of the finest patches of grassy forest-lands have been rendered perfectly barren and unprofitable by the destruction of the trees for firewood alone. It may be advanced that in the colonisation of new countries this cannot be avoided; but it would be a wise course on the part of the authorities to plant young trees where the old ones have been cut down.

410. *Absence of Malaria on its Marshy Lands attributed to deodorising influence of Carbonic Acid Gas.*—While the presence of deleterious gases from human causes is infinitesimal, the absence of malaria from natural influences is characteristic of the Australian climate. Although the thermometer reaches

as high as, if not higher than, in China, and there are extensive marsh-lands and swamps similar to what exist there, yet the class of diseases arising from them is unknown in Australia. This is accounted for in a general manner by medical men, from the dryness of the atmosphere and the rapidity of evaporation, which carries off the deleterious gases as soon as they are generated. No doubt these have the effect of lessening the accumulation of malaria over marshy lands; but as New Zealand enjoys the same immunity from malarious diseases, though the climate is very humid, and the extent of marsh-lands greater in proportion, there must be some other atmospherical agency at work to neutralise the generation of malaria. This we take to be the presence in the atmosphere of a large percentage of carbonic acid gas, as detailed in a previous section. We contend that this constituent is the great scavenger of the air that sweeps away all the impure exhalations of the earth. While it sustains the life and structure of vegetation, it destroys the noxious gases generated by decayed vegetable and animal matter. In its pure state, without a due admixture of oxygen, it is considered the most deadly of all gases to inhale, as witness its effects on the suicide by charcoal fumes, the suffocated dog in the *Grotto del Cane*, and the bones of victims in the Upas Valley. On the other hand, when combined with the other constituents in its minute volume, it is not only innocuous, but serves the purpose of assisting to maintain a healthy condition of the air we breathe. As charcoal deodorises fetid water, so may carbonic acid gas deodorise malaria. Hence probably the presence in the Australian air of a large proportion of this gas may account for the absence of malaria upon marsh-lands, where, under different conditions, it would exist; as, for example, if Australia were situated in the northern hemisphere, under latitudes corresponding to those of China. This suggestion opens up a very interesting subject of inquiry regarding the properties of carbonic acid gas as recently investigated by *savans* on the Continent.

411. *Effects of Carbonic Acid Gas on the Human Constitu-*

tion by Experiment.—Although this gas, when pure, causes asphyxia if inhaled, there are instances of it not having produced this disastrous effect—a proof, as Dr Demarquay rightly observes in his 'Pneumatologie Médicale,' that it is not poisonous *per se*, as has been contended by many. The following instances quoted by him are curious:—Pilâtre de Rozier, the unfortunate aeronaut, had the courage to engage in the following hazardous experiment, in order to ascertain how long an atmosphere of carbonic acid gas could be borne. With the help of a ladder he descended into a brewer's vat which was filled with that gas, and at once felt a slight warmth all over his body, causing an increase of perspiration. He felt a pricking in his eyes, which obliged him to shut them often, and when he attempted to draw breath he was prevented by a violent sensation of incipient suffocation. He now wanted to get out of the vat again, but could not find the ladder; and the want of fresh air becoming more and more pressing, he was seized with vertigo and tingling in the ears. He did, however, get out; but although he could now breathe freely, he could distinguish nothing with his eyes, and his sense of hearing was almost gone. He was mad enough to repeat the experiment, and found that, so long as he could do without breathing, he could walk and even speak in the gas. Another bold adventurer, Dr Constantine James, of Paris, laid himself down in the far-famed *Grotto del Cane*, near Naples, and kept his breath some time in order to observe the action of the gas on his senses. No sooner did he risk an inhalation than he was seized with vertigo, and obliged to raise his head out of the stratum of gas—which, being heavier than atmospheric air, is not very deep—in order to breathe pure air. In a few minutes the painful sensation was gone, and the doctor tried again, but this time he was more prudent, and inhaled only a small quantity. The same symptoms returned, and he felt a sort of boiling about his forehead—a sensation which he compares with what one feels when, in drinking champagne, a little of it gets into the nostrils. The same author states that when he was there, the keeper of the place had a dog

which he was in the habit of laying down in the grotto with its paws tied, for the amusement of visitors. The animal would show great anxiety, struggle for some time, and then lie as if dead. At this moment the keeper would take it up, carry it out into the air, and untie its legs. By degrees the animal would return to life again, and then run away for fear probably of being subjected to the same ordeal, which, however, used to be inflicted on it five or six times a day.

412. *Carbonic Acid recommended as a Medicament by Dr Le Play.*—Thus it would appear that carbonic acid gas—the exhalations of which from mineral and vegetable sources are so much dreaded—is, after all, not a poison; only that, when inhaled in larger doses than suits the respiratory organs, it becomes fatal to animal life, just as an overdose of some healing medicine may produce death. Having satisfied themselves on this point, some French physicians, pursuing the inquiry by experiment, have discovered that it may be used as a medicament when inhaled in small doses mixed with common air. On this subject an interesting paper was recently read before the Academy of Sciences by Dr Le Play, an eminent medical practitioner and experimentalist. He found that this gas, mixed with air, excites circulation in the mucous membranes with which it is in contact. Hence it may exercise a powerful tonic action in bronchial catarrh. It should therefore, in his opinion, be prescribed in all cases in which a pulmonary affection is accompanied with congestion, a direct tendency to inflammation, and especially spitting of blood, because then carbonic acid will carry the inflammation to a higher pitch, and thus modify the vitality of the tissues. This may account for the circumstance that catarrhal affections are alleviated, and sometimes cured, by draughts of champagne, which evolves carbonic acid largely.

413 *Healing Effects of Carbonic Vapours in Gasworks.*—In like manner it is chiefly owing to the presence of carbonic acid gas in the vapours evolved in the purifying chambers of gasworks that they have been resorted to by patients as a cure for the hooping-cough; and the number of recoveries

among children from that distressing complaint in Paris is evidence of its efficacy as adopted by Parisian physicians. Still there have been obstinate cases, and even some in which the patients actually got worse instead of being relieved—circumstances which led several practitioners to condemn the remedy altogether, until Dr Burin Dubuisson succeeded in explaining the cause of this extraordinary difference in the results. He has shown by reliable experiments—1st, That the proportion and composition of the gaseous substances evolved are never the same in different gasworks; 2d, That the beneficial gases were mixed up with deleterious gases, the latter even preponderating in some instances; and, 3d, That even in the same gasworks the proportions change according to the hour of the day. To obviate these inconveniences, Dr Dubuisson has composed a liquid which he calls *gazeol*, and which, in evaporating—doing so very rapidly in a water-bath—will fill a close chamber with all the beneficial emanations for which gasworks are recommended. Thus several children are admitted into a room 25 feet long by 16 feet in breadth, and 14 feet in height. A tea-spoonful of gazeol is introduced into an open phial, which is put into a water-bath always kept at the same temperature. The gaseous exhalations thus produced may occasionally affect the patients disagreeably, but the operation has been performed three times a-day at the Orphan Asylum in Paris with the most beneficial results. At first it was only tried in cases of a common or of a hooping cough, but it has since been found extremely useful in catarrhal bronchitis. In the first place, it weakens the intensity of the cough very materially; it prevents it during the whole time the patients inhale the emanations; and it prevents it returning in fits afterwards.* It has not been found beneficial in bronchitis dependent on miliary tuberculosis, and in tubercular consumption; but cases of catarrhal bronchitis have been cured in from six to twelve days, instead of requiring a month or two's treatment. No doubt, as the subject is further investigated and experimented on, a gaseous compound, with carbonic acid gas as the basis, may be discov-

ered that will prove curative of tubercular diseases of the respiratory organs.

414. *Tetrachloride of Carbon a valuable Anæsthetic.*—While the French physicians are thus employed in determining the healing properties of carbon and its combinations, we find our own medical practitioners equally active in the same direction of rendering their discoveries in chemistry available for alleviating the sufferings of afflicted humanity. In the 'Lancet' the following notice appears:—"We are glad to announce the introduction of a new anæsthetic, which, if further experience confirms the results hitherto obtained, promises to be of remarkable value. Dr Protheroe Smith has been making some observations on the administration by inhalation of the tetrachloride of carbon ($C\ Cl_4$), of which we wait for a fuller account. In the mean time, from our own observation, we may state in favour of this agent that it has a pleasant odour, somewhat resembling that of the quince. We understand that anæsthesia is rapidly produced by it (in some cases in the space of half a minute), that the condition appears to be easily sustained with or without entire loss of consciousness, and that the effects pass off very quickly. There is not usually, we learn, any excitement or struggling before anæsthesia supervenes, and its use is not followed by the sickness which is sometimes so troublesome a feature of chloroform. A point of great interest in relation to the tetrachloride of carbon is the property which we are told it possesses of immediately allaying pain arising from any cause. In a large number of instances it has been successfully employed for the relief of headache and dysmenorrhœal suffering. Dr Protheroe Smith has found it of great value in inducing quiet and refreshing sleep. He has also employed it in midwifery, and finds that it removes pain without necessarily destroying consciousness or interfering apparently with the expulsive efforts of labour."

415. *Carbon in a Solid, Liquid, or Gaseous Form, not Poisonous.*—As evidence that carbon, either in a gaseous or solid form, is not poisonous *per se*, but, on the contrary,

wholesome, we may indicate its increasing consumption in such articles of food as charcoal biscuits, and the quantity of gas inhaled and swallowed in drinking aerated waters. Even when respired in the crude form of smoke, mingled densely with the atmosphere of cities, it has not been found to increase the amount of mortality or disease, as compared with country districts, where the inhabitants breathe a comparatively pure atmosphere. On the contrary, there are sufficient data for concluding that the smoke of the city furnishes a sanitary equivalent in neutralising the poisonous gases arising from insufficient drainage and overcrowding in houses. So that in exhuming our coal-deposits, and consuming them in dwelling-houses and manufactories, civilisation is stepping in to restore to the northern atmosphere some of its original element buried for countless ages; and however much may be said against the discomforts of smoky towns, the evolution of carbonic gas by such means may assist in purifying the air of more deadly gases. It has not been shown that the respiration of smoke is dangerous, or destructive of human life, if we may judge by evidence produced at *post mortem* examinations of aged people in London, where the lungs frequently became discoloured by the inhalation of smoke, without producing any appearance of disease.

416. *The Climate of Australia considered by Physicians as Curative of Pulmonary Diseases.*—Be that as it may, it is evident that the properties of carbon in a gaseous form, as well as in conjunction with fluids and solids, are becoming better known and appreciated by medical men, and we may hear more of its use in the class of diseases indicated by Drs Le Play and Dubuisson. There is a wide field of inquiry and experiment open in this direction that is deserving of practical investigation. Moreover, it is now generally acknowledged by advanced medical practitioners in England, who base their views upon the reports of their *confrères* in Australia, that the climate of that country is more conducive than any other to the cure of pulmonary consumption and all diseases of the respiratory organs. It has been found

that persons afflicted with these prevailing complaints of the mother country on arrival there recover in a most surprising manner, especially if they have not reached their last chronic stage. Even then existence is prolonged beyond what it would have been at home, and the patient is imbued with a temporary renewal of health until the final collapse occurs. The number of instances of recovery is yearly increasing; and it is now the common advice of medical men in such cases, after all other curative efforts have failed in northern climates, to advise patients to emigrate into temperate climes south of the equator, or at all events undertake the long voyage to Australia and back, remaining a short time in the country. Not only have laymen followed this advice, but some professional men subject to consumption have put it into practice, and found the beneficial results of the change of climate all that and more than they expected. One doctor gave up his practice in England and proceeded to the colony of Victoria, where he considered himself entirely free from pulmonary disease after a year's residence; and in two years published his experiences to the world in an interesting and instructive little volume 'On Australian Climates, and their Influence in the Prevention and Arrest of Pulmonary Consumption,' by S. Dougan Bird, M.D., L.R.C., P.L.: Longmans, London.

417. *Dr Bird's Experiences of its Climate as a Curative Agent in Consumption.*—Although giving expression to his views in a thankful vein of recovery from a fatal disease, Dr Bird gives an impartial statement of his experiences of climatic influences on health both in Europe and Australia. He looks upon the change of climate from place to place in the British Isles as of no avail in arresting pulmonary consumption; and when patients obtain temporary relief by visiting the most favourable localities on the Mediterranean merely to get over the winter, the insidious disease is not arrested. It has long been a question among medical men, Whether this disease, once set in, was curable? and the general result of cases led to the conclusion that it might be alleviated but

not cured. Dr Bird disputes the conclusion, and holds that its progress may be rendered nugatory, but not in European climates. He then states that when he left England he was a confirmed *poitrinaire*, gradually becoming enfeebled and emaciated. On the voyage out he picked up some strength; and after not more than three months' residence in Melbourne he had gained 16 lb. in weight. In twelve months he considered himself completely cured, and a stronger man than ever he had been in Europe. He considers that there are remarkable peculiarities in the Australian climate that not only alleviate complaints of the lungs, but have the power of throwing off actual disease and preventing its return. This he attributes to the abundance of sunlight, the prevalence of fine weather, low degree of humidity, a great amount of ozone in the atmosphere, &c. In all these beneficial influences of climate upon the consumptive patient we entirely agree, and can fully vouch for the accuracy of his statements. But we cannot help thinking that some more potent influence exists to bring about this remarkable curative power in the Australian atmosphere over diseases of the respiratory organs than merely greater degrees of light and heat, and the general purity of the air inhaled, compared with these existing in the country where the disease originated.

418. *In course of time it may become the grand Sanatorium of the World.*—The intelligent reader will readily suppose that we attribute this property of the Australian climate to the presence of a larger volume of carbonic acid gas in the atmosphere there than exists here. Putting the medical testimony of Dr Le Play on the curative powers of carbonic acid in juxtaposition with Dr Bird's experiences of the Australian climate, we are fairly justified in drawing this inference, irrespective of the botanical evidence we have furnished in a previous section. Here we have positive medical data in support of our theory of disparity in the volumes of the atmospheric constituents in the south temperate zone as compared with the north, or at all events sufficient data to

show that one region contains curative elements in the air for diseases contracted in the other. This conclusion gives rise to the question whether tubercular diseases of the lungs, bronchitis, and other complaints of the respiratory organs, are not caused by the diminution of carbonic acid gas in the northern climates, as well as the ordinary predisposing causes of cold, damp, and the like. Moreover, it is not unphilosophical to infer from the foregoing data that, during the earlier epochs of animal existence, the carbon and oxygen were in greater volume than afterwards in the north hemisphere, and as those diminished, this assisted in the extinction of species. At first disease would undermine their vigour, which would be transmitted in an increasing ratio through generations, until the remnants of each race became extinguished from sheer exhaustion of vital energy. On such a hypothesis may we not explain the prevalence of disease amongst the human race in the north hemisphere, which in time will lead to further physical degeneration? In that case the temperate regions of the south hemisphere, with their reinvigorating climates, will be the places of refuge for the exhausting humanities of the north, and Australia become the grand sanatorium of the world.

419. *Transportation to Australia formerly a Premium to Criminals.*—In this respect Australia is the most valuable of the British possessions abroad, inasmuch as the benefits that accrue to the colonists by its hygienic advantages will continue long after the gold-fields, which so suddenly advanced her material prosperity, are exhausted. It is to be hoped that for the future the social and political condition of the free communities established there may continue as morally healthy as the salubrious climate. When we look back upon the original destiny of this country as the receptacle of the dregs of humanity, we cannot but rejoice at the altered prospects of native-born Australians during succeeding generations. It is true that through the agency of criminal labour the unprofitable wilderness was first brought into cultivation. But the demoralisation of society by their presence counter-

acted in a great measure the benefits of their labour. Happily that evil is passing away, and the next generation will find the convict leaven of the parent state expunged from the community. It was but recently that all friends of moral and social progress in Australia grieved to find an enlightened Government persisting in casting on these shores the offscourings of British prisons, to create a demoralised malaria among colonists enjoying the healthiest amount of social and political institutions in the world. Irrespective of these considerations, this line of policy was offering a premium to criminals upon hygienic considerations alone. We can readily understand how, in this country, the prisoners find it a punishment to be immured in dreary dungeons, or forced to labour at public works in all kinds of weather; and also how their attenuated forms excite the benevolence of philanthropists, after breathing the vitiated air of their prisons for some years; while the rigour of this northern clime gathers its harvest of victims, notwithstanding the generous prison fare on which they are fed. It was very different, however, when the convicts were transported to Australia, where the labour and short imprisonment assigned to them were comparatively no punishment at all. There the majority of transports had abundance of the necessaries of life, and some of its luxuries, while they were set to the easy and pleasant occupation of herding cattle and sheep, growing robust, and respiring an atmosphere that not only cured the constitution of morbid diseases, but revived their spirits until *their longevity was increased.* Under such favourable climatic conditions transportation was no punishment. It became a kind of reward given to the persons selected by a paternal government. This abnormal policy, as we have remarked, has nearly ceased, and the emigrants sent to the Australian shores are of the most deserving class; while those who voluntarily proceed thither for the benefit of their health are an acquisition to the colonies when they recover. We trust the day is not far distant when even British statesmen, exhausted by the harassing cares of political life, may extend

their vacation tour to this sunny south land, and return re-invigorated in body and mind to their arduous tasks, with their organs of speech and respiration strengthened by the voyage.

420. *Remarkable Effects of the Climate on the Fecundity of European Females.*—While the male sex generally acquire increased bodily and mental vigour in the Australian climate, the female European undergoes similar, if not more remarkable, constitutional invigoration. An Englishwoman of five-and-twenty will retain her vigour undiminished for eight or ten years, and sometimes a rejuvenescence takes place in a healthy woman of thirty; while the lives of the aged with impaired constitutions are prolonged. But the most remarkable change effected by the climate, according to medical authorities, is the renewal of fecundity at a comparatively advanced age, and, in numerous well-authenticated cases, the bringing on of fertility after many years of barrenness in the mother country. This is now becoming so well known that some married couples without families emigrate to Australia with the prospect of having children; and where an heir to an estate is wanted, the longing mother takes her departure for the wished-for land where her hopes may be realised. And when so blessed, she looks with delight upon her offspring as nothing inferior to any in her native land. Indeed, it may be said that the native-born children of Anglo-Saxon parents are if anything an improvement upon the original stock. Nowhere have we seen such bright intelligent faces, with clear complexions and robust frames, as we have seen among the youth of both sexes in Australia. The beauty of the young women, especially those born in Victoria and Tasmania, where the climate is coolest, is the theme of all travellers and newly-arrived settlers, who consider them equal to the fairest English beauties, because flaxen hair predominates. At the same time it must be stated that the bloom of the Australian women is not so permanent as that of their English sisters. The roses that bud on their cheeks arrive sooner at full bloom and then decay. So is it with the whole constitution. The

child arrives at maturity two or three years sooner, and the woman declines several years earlier.

421. *Longevity, and Fatal Diseases of short Duration, in Australia.*—What may be the longevity of the native-born race as compared with their progenitors, there is not sufficient time yet to determine. We are of opinion that the lamp of life burns more quickly in that clime than in this; so that the individual may not reach an extended number of years. But if we take into consideration the long days and fine salubrious weather that prevail, the term of existence is increased beyond the most favourable conditions of long life in Europe. Even when disease attacks the patient in Australia there is rarely any lingering of chronic complaints. In that region the cure of disease is generally more rapid than in Europe, and so also is the progress towards decay or death. You are either becoming rapidly convalescent from an illness, or hurrying into your grave; there is no long lingering on its verge.

422. *Its Climatic Influence in checking the spread of Epidemics.*—According to Dr Dougan Bird, the prevailing types of disease are diarrhœa, dysentery, dyspepsia, inflammation, congestion, heart disease, apoplexy, liver complaint (but not scrofulous), and others of an individual character brought on by excess or irregularity of living. Although there is a general absence of endemic diseases, yet when fevers occur their course is very rapid, especially among children, where there is proportionately a greater mortality than among adults, which he attributes to their being stuffed with animal food. Of epidemic diseases nothing of a serious nature has been known to have passed over the Australian colonies since their foundation. Asiatic cholera in its virulent form is unknown; and where it has appeared at some of the seaports on board ships arriving from northern countries, it has rapidly disappeared in quarantine, assuming a mild form with small amount of mortality. The same remarks apply to small-pox, against which, notwithstanding the salubrity of the climate, stringent regulations are enforced to prevent its introduction.

On one occasion within our knowledge these regulations were evaded at the port of Melbourne through means of a false bill of health, and this scourge of the north hemisphere was introduced by some immigrants into that city. Several cases of a virulent form were discovered, and the government medical staff adopted the best precautions they could devise to prevent it spreading among the inhabitants. Fortunately this did not ensue, and all those suffering from the disease when they came on shore rapidly recovered, excepting one youth, who died. Without detracting from the efficiency of the medical assistance in arresting its progress, we are inclined to consider that the exceptional nature of the climate in not fostering tubercular diseases had as much, if not more, to do in checking it, otherwise it might have become localised in Melbourne, and ultimately spread throughout Australia, and established itself as an endemic disease in that hot region, as it is in India and China.

423. *Salubrity of Melbourne, Sydney, and Adelaide under exceptional Conditions.*—Taking the three chief cities of Australia—namely, Melbourne, Sydney, and Adelaide—as examples of towns situated in a hot climate, with a low degree of mortality, the result is very remarkable. To the western boundary of Melbourne a swamp of greater extent than the city itself lies sweltering under the hot summer sun, with the sluggish river Yarra Yarra flowing along its margin. Yet no medical reports refer to this swamp as the generator of deadly malaria; whereas if it were in China, or even in Italy, marsh-fever would be the prevailing disease, with, doubtless, a large mortality from malarious diseases among the city population. At Sydney what are called the "Botany Swamps" lie to the south of the city, but they do not present so unwholesome a sight as that at Melbourne, as the soil is of a very sandy nature. Still, under northern conditions of climate and summer-heat, these should evolve marsh-miasma, which they do not; and Sydney is the healthiest city in Australia. Between the city of Adelaide and the shore of St Vincent Gulf, where the entrance to the port is distant

some twelve or fourteen miles, half of the intervening land is nothing but a mud-swamp intersected by small creeks that rise and fall with the tide in the gulf. Looking upon this locality when it is low-water, during a hot summer day, it presents all the conditions of a pestilential spot capable of spreading its deadly influence around for a circuit of at least one hundred miles; yet Adelaide, though the least healthy of the three cities enumerated, is not an exception to the general salubrity of Australian towns. The marshy lagunes we have mentioned approach nearer than anything we have seen to the muddy lands and creeks around Shanghai; and it is reasonable to infer that, were these situated in the same latitude in the north hemisphere, they would also be generators of marsh-miasma. It does not say much for the foresight of those who pitched upon these sites for the three chief cities of Australia; for had the climatic relations been the same as in corresponding regions of the north hemisphere, in all probability they would have ranked with the most unhealthy towns in Asia or Europe.

424. *The Salubrious Climate admits of Sleeping out in the Open Air with impunity.*—In the government report on the climate of Victoria the following passage occurs:—"The unsettled habits and irregular mode of life necessarily attendant on the rapid colonisation of a gold-producing country make it impossible at first to ascertain with certainty the effects of the climate on the health of the population. There can be no doubt that the character and severity of the prevalent diseases must be materially affected by the rapid vicissitudes of temperature occasioned by extreme heat and low mean humidity; but, on the whole, there is every reason to believe that the climate of Victoria is one of the most salubrious in the world." This applies more particularly to the gold-mining, pastoral, and agricultural populations, or those exposed to the vicissitudes of a country life in a new colony, where a reckless mode of living is carried on, that in corresponding northern latitudes would create an excessive degree of mortality. It is a common practice, when travelling in the inte-

rior beyond the settled districts, to sleep in the open air, which may be done with impunity during the greater part of the year. Night after night have we slept under a gum-tree, wrapped in an opossum-rug, a saddle for our pillow, and a fire at our feet, without contracting the slightest cold or rheumatic affection. To attempt such a mode of rest during the night, under ordinary circumstances, in any European climate, would be sure to bring on some serious ailment at the first attempt. The highest rate of mortality in the colony of Victoria was in 1854, during the gold-discovery, when 78,000 immigrants arrived by sea in bad sanitary condition; yet the deaths did not exceed the ordinary rate of 20 per 1000. But the best comparative statistics on this head cited by Dr Bird are the rates of mortality among the British troops on foreign stations, where Australia is at the bottom of the scale. Without entering into detail, we find the highest to be 30 in the 1000 at Bermuda; while in these colonies generally it is not more than 11 per 1000.

425. *Experiences in the Moist Climate of New Zealand indicate its Salubrity.*—Here it may be said again that if the climate of Australia were as humid and the ground as damp as it is in Great Britain, the settlers who attempt to pass the night in the open air of a forest would rise in the morning with all the aches and rheumatic twinges that such an act would bring here. But we may instance New Zealand as a region where this may be done with impunity also, though it is more humid than England, and its hottest latitudes are a region of marsh-lands, without generating malaria. We have travelled through part of that region during its wettest period, when our party were without a dry piece of clothing for several days, marching through swamps soaked with rain, our boots filled with water which had free egress and ingress by holes cut in the toes and heels. At night we lay upon the soft ground, with only a blanket on propsticks to keep off the rain, and in the morning we have wakened with our bodies literally immersed to the depth of two or three inches in water. Despite exposure to the weather in this manner

for a week, and breathing an atmosphere more or less saturated with humidity, none of us experienced the slightest ailment afterwards, and at the time only the discomforts of this mode of travelling.

426. *Military Medical Reports exhibit low rates of Mortality and Disease among the Troops.*—During the unhappy wars which have attended our colonisation of these islands, the British troops encountered all the vicissitudes of weather, marching through marsh-lands such as we have described, and yet they enjoyed the highest state of health, as shown by the following brief statement in the 'Lancet':—"It is probable that the British army engaged during the late war in New Zealand enjoyed better health, and sustained fewer losses, than in any previous campaign. Dr Mackinnon attributes this to the very beautiful and salubrious climate; and he adds that the change which it effected in the men of regiments arriving from India was most marked. Sickly and sallow-complexioned on arrival, they soon lost the marks of ill health engendered by tropical service, and regained health and strength while undergoing arduous service in the field. The late Staff-Surgeon, Dr Thompson, in his admirable 'History of New Zealand,' pointed out the importance of that country as a sanatorium for our Indian invalids. It is not a little curious that there is an entire absence of malaria in New Zealand." This immunity from miasmatic influences engendering disease impressed Dr Thompson all the more, as he saw extensive marsh-lands under a hot climate, which in India would have rendered them the hotbeds of malaria. It is therefore not unscientific to infer that some more potent influence must be at work in neutralising the miasma that arises from the decayed vegetable matter in these swamps, which extend for hundreds of miles through the interior, than the ordinary effects of strong winds and stormy weather in clearing the air of noxious exhalations; and that potent influence we take to be the presence of a larger volume of carbonic acid gas in the atmosphere of New Zealand than exists in India. Thus it may be found by actual experiment

that what causes the remarkable growth of carboniferous vegetation there may also account for the absence of malaria.

427. *High Degree of Health enjoyed by the New Zealand Colonists.*—Of the general salubrity of the New Zealand climate there is abundant evidence to be found in the medical statistics issued in the settlements; which, though varying in degrees of latitude and temperature to a much greater degree than the British Isles, agree in the immunity from endemic and deadly epidemic diseases enjoyed by the colonists. After enumerating the leading characteristics of the climate, one account states:—"It is almost needless to add, that the most robust health is enjoyed by almost all persons who live in such a climate. The doctor's occupation would be nearly gone, but that marriages are undoubtedly rendered more prolific by the same genial air which rears all the children in such rosy vigour." This will lead the reader to infer, also, that the same influences are at work in curing sterility in women there as we have seen to exist in Australia; but of this we have not so many marked cases.

428. *Dr Dieffenbach's Remarks upon the Absence of Endemic Diseases, and Salubrity of Climate.*—Dr Dieffenbach, who paid especial attention to the meteorology and sanatory condition of New Zealand during his residence and travels throughout the greater part of the two islands, affords us the following testimony to the salubrity of its climate:—"As the atmosphere, by its moderate warmth, its humidity, and constant current, is peculiarly favourable to the vegetative powers, as we see in the luxurious growth of plants, so from the same causes it suits the human frame. In the families of the missionaries and settlers I observed no deviation from the original stock; the children grow well and strong, with fresh and rosy faces, and I am satisfied that in this respect New Zealand is in no way inferior to Great Britain. A humid and temperate atmosphere acts especially upon production, both as it regards growth of the body and the numerical strength of families. Nutrition and reproduction are in good order; in respect to the numerical strength of families,

the climate seems to be particularly favourable to the increase of population—at least all the Europeans have large families. We see the effect of this humid climate in certain diseases, to which Europeans first arriving in this country are often subjected. These are abscesses, or boils, and eruptive diseases; neither, however, of a malignant character, and both disappearing without medical aid. Amongst the natives, carbuncles and diseases of the mucous membranes are common: here, however, other causes are acting, of which I shall speak more hereafter. The European, when once acclimatised, does not suffer from any of these causes. True inflammatory diseases are uncommon; the south-east wind of New Zealand is never as keen as our north-easter; but, in consequence of the moist climate, such diseases always assume the character of catarrh. I am not aware that any endemic diseases exist in New Zealand; influenza, however, and sometimes croup, appear epidemically. If care is not taken, rheumatisms also make their appearance. But it is certain that causes, which in England would produce violent colds and other injurious results, pass over in New Zealand without any bad effect, even to those colonists who are in delicate health. The purity of the atmosphere, resulting from the continual wind, imparts to the climate a vigour which gives elasticity to the physical powers and to the mind. Heat never debilitates, not even so much as a hot summer's day in England; and, near the coasts especially, there is always a cooling and refreshing breeze. The colonist who occupies himself in agriculture can work all day, and the mechanic will not feel any lassitude, whether he works in or out of doors. From all this I draw the conclusion that, as regards climate, no country is better suited for a colony of the Anglo-Saxon race than New Zealand. Invalids rapidly recover in this climate; and there is no doubt that the presence of numerous thermal waters in the North Island, and the attractive scenery, will make New Zealand the resort of those who have been debilitated in India, and are in search of health."

429. *Hints for a New System of Medical Practice by Aero-*

pathy.—From our own experiences in sojourning for a short time and travelling through these islands, we can fully endorse all that the learned doctor has stated in favour of the New Zealand climate; and, in like manner, from a much longer residence and extent of travel in Australia, we accord with all that Dr Bird and other medical authorities pronounce regarding the salubrity of that greater region in the salubrious atmosphere of the south hemisphere. On the principle that "prevention is better than cure," we would advise those who have weakly constitutions to avail themselves of nature's vast laboratory there, and inhale fresh draughts of pure air highly charged with the vital elements of oxygen and carbon, to a degree not found in the vitiated atmosphere of the north. And might not the physician, also, take a hint from the foregoing data in adopting a practice for the cure of pulmonary consumption and other diseases of the respiratory organs, more consonant with the natural remedies existing in the southern atmosphere? Formerly the treatment of such diseases was on the same basis as most complaints, the cure of which was through the medium of the stomach, into which all sorts of mineral and vegetable ingredients were emptied, of which only the smallest whiff of their essence reached the affected parts. This mode of treating the organs affected by breathing air has been partially modified by the inhalation of medicaments with baths of heated air, and to a certain extent with success. But these medicaments are all of an extraneous character more or less to the vital elements of the air; or if not so, they consist in simply inhaling the vapour of hot water. Now, would it not be well to carry out Dr Le Play's system of respiring carbonic acid gas diluted with pure ordinary air; or what, in our opinion, would be better, placing the patient in a chamber constructed so as to admit of a factitious atmosphere highly charged with that constituent, or with oxygen gas, as the case would sugges the treatment to a skilful medical practitioner? In pursuin such a system it would be necessary to proceed cautiously i administering the increased volumes of carbon and oxyge

and care should be taken that the vitiated air had free ventilation. This suggestion we give out with all due modesty on our part, as simply one of the deductions from the great principle involved in this dissertation, on the apparent differences in the constituents of the south and north aerial hemispheres. And as there are systems of allopathy, homœopathy, and hydropathy in the practice of medicine, there is no reason why a system of *aeropathy* might not be tried for the relief of afflicted humanity; and it is just possible that it may turn out to be the most successful of all the "opathys." If the first experiments were found to be successful in a small chamber, the system could be extended, and large apartments used, where many patients might inhale the reinvigorating medium; and thus a building of iron and glass as large as the Crystal Palace could be rendered one of the grandest *sanatoria* in the world for the cure of diseases of the respiratory organs.

430. *Scope for improving the Science of Medical Practice.*—Hitherto it would appear that those who study the principles of diseases and their cure cling too much to administering crude medicinal substances, as distinguished from their refined or elementary condition, especially those that form the life-sustaining elements in the atmosphere. As it is understood that the greater number of endemic and epidemic diseases enter the system in a gaseous or elementary form, it is logical to conclude that in order to arrest or cure their deleterious effects, a similar system of impregnating or inoculating the constitution with counteracting gaseous elements should be pursued. As at present practised, medicine is more an art than a science, whereas it should be the *ne plus ultra* of the physical sciences. Nevertheless the highest praise is due to those eminent members of the medical profession whose aim is to progress in the field of discovery opened up by experimental science.

431. *Professor Simpson's Address to the Graduates of Edinburgh University.*—On this head we find the most advanced views recommended by Professor Sir J. Y. Simpson

in his address to the graduates of Edinburgh University at the close of the session of 1867-68, wherein he makes the following remarks:—"During the present century the scalpel and the microscope have developed for us a vast amount of new and most invaluable facts in the way of morbid anatomy and pathology; and this field is by no means yet exhausted. Science has, at the same time, laboured most successfully to place in the hands of the medical practitioner means and instruments by which we can perceive and discover the pathological anatomy of various organs within the body of the living individual. Thus, for example, by the invention of the ophthalmoscope we can look into that dark inner chamber of the eye where shadows and soul—where matter and mind—so mysteriously meet and commune with each other, and can distinctly see the various diseases that may affect its walls or its fluid contents. The laryngoscope exposes fully in a similar way to our inspection the interior of the organs of the voice. The endoscope reveals to us the conditions of other internal canals and organs. While to the instructed ear of the physician the stethoscope whispers back the diversified morbid conditions of the lungs—telling wondrous secrets as to their exact nature and precise seats. In this great line of discovery new victories are certain to be won. Do you search out other additional physical means of diagnosis for these and other viscera. Possibly even, by the concentration of electrical and other lights, we may yet render many parts of the body, if not the whole body, sufficiently diaphanous for the inspection of the practised eye of the physician and surgeon. But the future greatest conquests for you, and for the coming race of physicians, are probably to be gained by researches in pathological chemistry and therapeutics. Pathological chemistry contains, doubtless, a rare and rich and most extensive mine of priceless ores and products for the future advancement of theoretical and practical medicine, and the only shafts yet attempted to be struck into its lodes have barely touched the mere surface of its boundless wealth. The most practical, however, and so far

the most important objects for calm, earnest, and faithful researches on your part, are probably to be found in the wide field of therapeutics. For the department of therapeutics, though the most important of all departments of physic, has hitherto been the most neglected of all—the one regarding which we know the least. The physiological modes of action of medicines form a labyrinth, or series of labyrinths, to which we as yet in fact possess no clue. Will you strive to unlock its secret entrances? Besides, we know not enough of the simple powers of our drugs; though the practice of medicine is essentially and ultimately the practical application of therapeutic agents. In making this statement do not misconstrue my meaning. The young physician trusts, perhaps, too much to mere drugs; the aged physician, perhaps, too little. The training of the philosophic physician consists in teaching himself when to give medicines, and what medicines;—and in what cases, and at what times, he should abstain from all drugs, and trust to nature, or to nature and hygienic means alone. He knows that a masterly inactivity is sometimes far more safe for his patients than the most efficacious but officious druggery. But when medicines are used, they should be the best and surest. We have a formidable farrago of them from the vegetable and mineral kingdoms—many inefficient, some doubtful, and almost all repulsive in character and form. A most extensive field for new investigations in this line lies temptingly open for the young and ambitious physician in the almost innumerable series of chemical compounds which modern organic chemistry has evolved. Among this world of new compounds will probably be yet detected therapeutic agents more direct, more swift, and yet more sure in their action, than any which our present pharmacopœias can boast of. It may be, also, that the day will yet come when our patients will be asked to breathe or inspire most of their drugs instead of swallowing them; or at at least, when they will be changed into pleasant beverages instead of disgusting draughts and powders, boluses and pills." Towards such a consummation is the tendency of

what has been advanced in the foregoing chapters on "The Air." All we attempt to point out in the disparity of the aerial hemispheres is to suggest to scientific men in Europe, who have no practical knowledge of the south hemisphere, to extend their investigations into that distant field, where they will probably find solutions to problems in the north for the better sanitary condition of the human race.

CHAPTER XX.

REMARKABLE PHYSICAL ASPECT OF SOUTH AMERICA.—*Conclusion.*

Brief notices of other climates in the south hemisphere, § 432.—Deadly nature of the climate in the western regions of Northern Africa, 433.—Comparative salubrity of the South African climate, 434.—Pestilential simoom of northern deserts compared with innocuous south hot winds, 435.—Salubrity of the climates of South America as compared with those of Central and North America, 436.—Humboldt's comparative tables of temperature in the north and south hemispheres, 437.—Tree-ferns grow in higher south latitudes than they do in north parallels, 438.—Humboldt's remarks on the controversy regarding the "New and Old Worlds," 439.—Assumed disparities in the east and west hemispheres have no foundation in nature, 440.—Arbitrary partition of the world into east and west divisions instituted by the Papacy, 441.—Artificial divisions in geography have no relation to natural divisions, 442.—Professor Agassiz on the remarkable geological phenomena of Brazil, 443.—Geology essentially a study of extinct vitality and physical activity, 444.—Geological dilemma of theory and observation, 445.—Importance of geological deductions to the body politic and government of a nation, 446.—Terrible effects of the earthquake at Tacna in Perú described by an eyewitness, applied to the London district, 447.—The epoch of great volcanic violence has passed away from Europe, 448.—Scientific missions should be appointed by the State, 449.—Different effects of the rarefied air in the Andes and Alps upon travellers, 450.—Speculative hypothesis on the carbonic structure of the sun, 451.—Spectral analysis of a telescopic comet seen in 1868, 452.—Determination by the spectrum to have an atmosphere of volatilised carbon, 453.—Remarks on a concentration of the physical sciences into one great science, 454.—Reflections on the desirability of accomplishing that object, 455.—All nature proclaims a principle of physical binary division dual in phenomena, 456.—Concluding remarks on the general subject of the work, 457.

432. *Brief Notices of other Climates in the South Hemisphere.*—Having entered so fully into the climatic phenomena

of Australia and New Zealand, we shall only briefly allude to those of the temperate regions in South Africa and South America, in support of our theory. The salubrity of the Cape of Good Hope has been known from the earliest days of the Dutch settlers, who, in their subsequent migrations inland, found the climate, even into the tropics, of a healthy character. It is true that at Cape Town fever appears occasionally as an epidemic, but it has been attributed to the bad drainage of the town and the filthy habits of the native population. In the far interior, where intrepid missionaries have taken up their abode to convert the heathen, the climate is described as being salubrious, and not injurious to Europeans as long as they keep from the low lands near the coast. Even there we have the testimony of travellers that there is a great disparity between the mild insalubrity of the climate, compared with the deadly nature of the tropical regions in Northern Africa, especially on the west coast.

433. *Deadly Nature of the Climate in the Western Regions of Northern Africa.*—"The whole of the Gold Coast is extremely unhealthy, owing, it has been alleged, to the sudden extremes of heat by day and cold by night, and to the thick sulphureous exhalations which rise from the valleys every morning, and diffuse themselves far over the surface of the land, spreading death and disease amongst the white population. In the midst of the most beautiful scenery, where trees and rocks and still waters and a delightful verdure give assurance of an earthly paradise, the angel of death lurks unseen, and strikes down his victims without warning, and while yet in the pride of their strength. The appalling number of deaths that have occurred in the various expeditions that have gone to the coasts and the interior of Western Africa, bear fearful evidence of the fatal nature of the climate. Upwards of a third of all the Europeans who have endeavoured to ascend the Senegal river have perished in the attempt; and nearly a half of those composing the expedition sent out by Government in 1816, to explore the River Zaire, shared a similar fate. On that occasion the comman-

der, Captain Tuckey, his lieutenant, the purser, ten of the crew, and four scientific gentlemen, all died within three months; and in the case of the Niger expedition in 1841, no fewer than 41 Europeans out of 145, including several officers and surgeons, died in less than two months. On this expedition numerous experiments were made to test both the air and the river-water, for the purpose of ascertaining whether they contained, as by many it was alleged they must, an extra quantity of sulphuretted hydrogen gas, supposed to be the agent of death in these regions, and to be due to the quantity of decomposing vegetable matter abounding in the rivers; but though conducted with the greatest care, from none of the experiments did it appear that the gas in question existed in excess, either in the air or the water. In Sierra Leone, perhaps the most unhealthy spot in these unhealthy regions, the mortality among Europeans is very great—few ships returning without losing some of their crew, and not unfrequently so many, that they are unable to leave the port until others have been obtained. The number of governors that have perished here from the effects of the climate, one after the other, is another striking evidence of the singular insalubrity of its atmosphere. The agent of death in nearly all these cases is fever, generally violent, and of the remittent type. Besides the known and alleged causes for this fatality, there are other and mysterious influences in operation; for in the case of the expedition commanded by Captain Tuckey, the journal of that lamented officer bore, that no climate could be finer than that they were enjoying; that the thermometer was never below 60° during the night, and seldom exceeded 76° during the day, no rain, and the sun seldom visible."* Might not these mysterious morbid influences in the air be accounted for on the hypothesis set forth in the foregoing pages; and that the malaria of the North African atmosphere is not neutralised or deodorised, in consequence of the diminished volume of carbonic acid gas and oxygen as its vital constituents?

* Art. "Africa," 'Imperial Gazetteer,' edited by Dr W. G. Blackie.

434. *Comparative Salubrity of the South African Climate.*—As a contrast to the deadly effects of the climate in North Africa upon European travellers, we may instance the fact that all the recent explorers in the southern division of that great continent have returned safe from the interior, most of them after many years of travel, to proclaim their geographical discoveries to the world. Of these heroes of discovery we need only mention Speke, Grant, and Baker, who traced the lake system south of the equator, as the true source of the Nile, all of whom returned to England in good health, notwithstanding the marshy regions they had passed through. But more surprising than these cases, or of any other African explorer, is that of the renowned Dr Livingstone, who, after sixteen years of residence and travel during his first expeditions alone, traversing South Africa from the Cape Colony into the far interior, where he crossed the continent from west to east in tropical latitudes, yet lived to reach England in comparatively good health, and surprised the whole of Europe with the recital of his travels in that *terra incognita.* Without entering into any detail, it will suffice to say that in travelling beyond the Cape Colony, some 1500 miles into the central region, he described his journey with his family in a waggon as "a prolonged system of pic-nicking; excellent for the health, and agreeable for those who are not over-fastidious about trifles, and who delight to be in the open air." As a medical practitioner he gives a most favourable opinion of the salubrity of these central lands, even on the borders of the Kalahari Desert, which is intersected by the tropic of Capricorn. He recommends that region as eminently suited for the cure of pulmonary consumption, if the patients could afford the time and means to reach it. Here, therefore, we have the testimony of the learned Doctor that the salubrity of the atmosphere in South Africa, together with its curative properties in tubercular diseases, corresponds with what Dr Dougan Bird states concerning the healing influences of the Australian climate in the same class of diseases.*

435. *Pestilential Simoom of Northern Deserts compared*

with innocuous South Hot Winds.—It may be advanced, in explanation of this apparently exceptional salubrity of an African climate, that the warm dry air of the desert sweeps away malaria. There is no doubt that the hot winds that blow from the deserts in South Africa are similar to those in Australia, as being innocuous to the human constitution and free from malaria. On the other hand, it is well known that the simoom or hot blast that sweeps over the Desert of Sahara is a pestilential wind, bearing disease and death on its wings. We are told by travellers who have experienced its effects, that the native Arabs on its approach dread inhaling the air so much that they fall on their faces and hold their breath to avoid its deadly influence. During its continuance fever and ophthalmia prevail—the latter being caused by the fine sand with which the air is charged. We have not heard of any baneful effects from the hot winds in South Africa, and we know from experience that there is no danger to be apprehended from breathing the hot winds in Australia. We have ridden across plains and over open forest-lands for many miles in the face of the Australian simoom, and we have experienced no ill effects from breathing it beyond the temporary discomforts of a parched tongue and nostrils, and the heated current of air reaching 110° of Fahrenheit.

436. *Salubrity of the Climates of South America as compared with those of Central and North America.*—South America is characterised by the same general salubrity of its various climates as South Africa, although there is not such a disparity between it and the northern continent as we have seen exists in its contemporary across the Atlantic. Yet the unhealthiness of the Mexican coast-lands and those of Central America are well known. On the other hand, the tropics of South America are famed for their immunity from pestilence, and comparatively cool climate. "There are no parts of South America so hot as we should be led to expect from its geographical position—a result produced by the operation of the trade-winds, atmospherical influences of the huge chain of the

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plains of Arabia are unknown on this continent. In the steppes of the Caraccas, the hottest region of South America, the temperature of the air during the day is only 98° in the shade, while it rises to 112° in the sandy deserts around the Red Sea. Throughout the whole basin of the Amazon, which comprehends between 2,000,000 and 3,000,000 square miles, the climate is neither very hot nor unhealthful, though under the equator. . . . Brazil, and the country extending from it westward, enjoy an equable and temperate climate." * "Chili, Buenos Ayres, the southern part of Brazil, and Peru, enjoy the cool summers and mild winters of a true *insular climate*, owing to the narrowness and contraction of the continent towards the south. This advantage of the southern hemisphere is manifested as far as 48° or 50° south lat.; but beyond that point, and near the antarctic pole, South America is an inhospitable waste." † Nevertheless there exists, in all the varied regions of that immense continent, an atmosphere of great purity, whether on the vast plains of the Llanos or the elevated regions of the Andes; while the coast-lands on the Pacific and the Atlantic are comparatively free from those deadly endemic diseases that prevail on the coasts of Central America and tropical North America. Without entering further into detail on this point, we shall close this portion of our subject by quoting Humboldt's remarks on the temperature of the southern continental masses, and the general fact that the south hemisphere is cooler and more salubrious than the north.

437. *Humboldt's comparative Tables of Temperature in the North and South Hemispheres.*—In illustration of this he shows that "the different degrees of latitude at which the *southern* extremities of Australia, including the island of Tasmania, of Africa, and America, terminate, give to each of these continents its peculiar character. The Straits of Magellan lie between the parallels of 53° and 54° south lat., and, notwith-

* Art. "America," 'Imperial Gazetteer.'
† Humboldt's 'Views of Nature.'

standing this, the thermometer falls to 44° Fahrenheit in the months of December and January, when the sun is eighteen hours above the horizon. Snow falls almost daily in the lowlands, and the maximum of atmospheric heat observed by Churucca in 1788, during the month of December, and consequently in the summer of that region, did not exceed 52° 2′ Fahrenheit. The Cabo Pillar, whose turret-like rock is only 1394 feet in height, and which forms the southern extremity of the chain of the Andes, is situated in nearly the same latitude as Berlin. Whilst in the northern hemisphere all continents fall, in their prolongation towards the pole, within a mean limit, which corresponds tolerably accurately with 70°, the southern extremities of America (in Tierra del Fuego, which is so deeply indented by intersecting arms of the sea), of Australia, and of Africa, are respectively 34°, 46° 30′, and 56° distant from the south pole. The temperature of the unequal extent of ocean which separates these southern extremities from the icy pole, contributes essentially towards the modification of the climate. The areas of the dry land of the two hemispheres separated by the equator are as 3 to 1. But this deficiency of continental masses in the southern hemisphere is greater in the temperate than the torrid zone—the ratio in the former being as 13 to 1, and in the latter as 5 to 4. This great inequality in the distribution of dry land exerts a perceptible influence on the strength of the ascending atmospheric current towards the south pole, and on the temperature of the southern hemisphere generally. . . . I subjoin the few certain data of temperature which at present we possess of the temperate zones of the southern hemisphere, and which may be compared with the temperatures of northern regions in which the distribution of summer heat and winter cold is so unequal. I make use of the convenient mode of notation in which the number standing before the fraction indicates the mean annual temperature, the numerator the winter, and the denominator the summer temperature." *

* Humboldt's 'Views of Nature.'

Places.	South Latitude.	Mean Annual, Winter, and Summer Temperatures.	
Sydney (Australia), . .	33° 50′	64°.6	54°.5 77°.5
Cape Town (Africa), . .	33° 55′	65°.7	58°.5 73°.2
Buenos Ayres, ...	34° 17′	62°.4	52°.5 73°.0
Monte Video, ...	34° 54′	67°.0	57°.4 77°.5
Hobart Town (Tasmania),	42° 45′	52°.5	42°.1 63°.0
Port Famine (Straits of Magellan), . . .	53° 38′	42°.6	34°.7 50°.0

438. *Tree-Ferns grow in higher South Latitudes than they do in North Parallels.*—In the same passage with the foregoing illustration of southern temperature this eminent authority on physical phenomena remarks as follows upon the remarkable growth of arborescent ferns in the south temperate zone, but without assigning any special cause to account for it :—"Some of the noblest forms of tropical vegetation, as for instance tree-ferns, advance south of the equator to the parallels of from 46° to 53°, whilst to the north of the equator they do not occur beyond the tropic of Cancer. Tree-ferns thrive admirably well at Hobart Town, with a mean annual temperature of 52°.5, and therefore on an isothermal line less by 3°.4 than that of Toulon. Rome, which is almost one degree of latitude further from the equator than Hobart Town, has an annual temperature of 59°.7 Fahrenheit, a winter temperature of 46°.6 Fahrenheit, and a summer temperature of 86°; whilst in Hobart Town these three means are respectively, 52°.5, 42°.1, and 63° Fahrenheit. In Dusky Bay,

New Zealand, tree-ferns thrive in 46° 8′ lat., and in the Auckland and Campbell Islands in 53° lat." From these examples we see that the extension of "some of the noblest forms of tropical vegetation" into temperate regions does not depend upon a high degree of heat in these latitudes, otherwise tree-ferns would grow in the open air in any of the warmer parts of the north temperate zone, which they do not. On the other hand, we find them growing in south temperate climate as cold as, if not colder than, England, where they would perish in the open air. We look upon these facts, therefore, pointed out by the greatest physical philosopher that has yet appeared, in illustration of the difference between the climatic relations of the north and south hemispheres, as further data in support of our theory that the atmosphere in the latter division of the earth is more highly charged with carbonic acid gas—the pabulum of vegetation—than in the former division.

439. *Humboldt's Remarks on the Controversy regarding the "New and Old Worlds."*—It must not be supposed, however, that Humboldt himself entertained similar views. On the contrary, he was such an advocate for the uniformity of all geognostic phenomena in point of geological time and terrestrial extent, that he argues against such a proposition in the structure of the earth, which he holds as one great continental mass being upheaved subsequent to another, after the lapse of several epochs. His views on this question were elicited during a scientific controversy between the *savans* of Europe and America regarding the geological ages of the *old* and *new* continents, to which he refers in his 'Views of Nature' as follows:—"The remark has been too frequently made by authors of general and well-attested merit that America was in every sense of the word a *new* continent. The luxuriance of vegetation, the vast mass of waters in the rivers, and the continued activity of great volcanoes, confirm the fact (say these writers) that the still agitated and humid earth is in a condition approximating more closely to the chaotic primordial state of our planet than the old continent. Such

ideas appeared to me, long before my travels in those regions, no less unphilosophical than at variance with generally acknowledged physical laws. These imaginary representations of an earlier age and a want of repose, and of the increased dryness and inertia with the increased age of our globe, could only have been framed by those who seek to discover striking contrasts between the *two hemispheres*, and who do not endeavour to consider the construction of our terrestrial planet from one grand and general point of view."

440. *Assumed disparities in the East and West Hemispheres have no foundation in Nature.*—It is important to observe that the two hemispheres alluded to in the foregoing extract are the east and west binary divisions of the earth, as delineated on the ordinary hemispherical maps of the world. This we infer from the text which this is intended to illustrate, wherein he compares the climatic relations of the whole American continent, north and south, with the entire continent of Africa, as follows:—"A number of causes, many of them still but little understood, diminish the dryness and heat of the New World. Among these are—the narrowness of this extensively indented continent in the northern part of the tropics, where the fluid basis on which the atmosphere rests occasions the ascent of a less warm current of air; its wide extension towards both the icy poles; a broad ocean swept by cool tropical winds; the flatness of the eastern shores; currents of cold sea-water from the antarctic region, which, at first following a direction from south-west to north-east, strike the coast of Chili below the parallel of 35° south lat., and advance as far north on the coasts of Peru as Cape Parina, where they suddenly diverge towards the west; the numerous mountains abounding in springs, whose snow-crowned summits soar above the strata of clouds, and cause the descent of currents of air down their declivities; the abundance of rivers of enormous breadth, which, after many windings, invariably seek the most distant coast; steppes, devoid of sand, and therefore less readily acquiring heat; impenetrable forests, which, protecting the earth from the sun's

rays, or radiant heat from the surface of their leaves, cover the richly-watered plains of the equator, and exhale into the interior of the country most remote from mountains and the ocean prodigious quantities of moisture, partly absorbed and partly generated;—all these causes produce, in the flat portions of America, a climate which presents a most striking contrast in point of humidity and coolness with that of Africa. On these alone depend the luxuriant and exuberant vegetation and that richness of foliage which are so peculiarly characteristic of the new continent. If therefore the atmosphere on one side of our planet be more humid than on the other, a consideration of the actual condition of things will be sufficient to solve the problem of this inequality. The natural philosopher need not shroud the explanation of such phenomena in the garb of geological myths. It is not necessary to assume that the destructive conflict of the elements raged at different epochs in the *eastern and western hemispheres* during the early condition of our planet, or that America emerged from the chaotic covering of waters as a swampy island, the abode of crocodiles and serpents."

441. *Arbitrary Partition of the World into East and West Divisions instituted by the Papacy.*—We submit that these arguments of Humboldt against the hypothesis of a supposed disparity between the eastern and western hemispheres do not affect what we have advanced regarding the atmospheric phenomena of the south and north hemispheres. The latter are natural divisions, where the seasons occur at opposite periods of the year; while the former is a mere arbitrary dissection invented by man for the aggrandisement of certain states during the early days of geographical discovery in the sixteenth century. "So powerful was the sway of the Popes in those days, not only over the religious government of Christendom, but the temporalities of the Christian powers, that no voyages of discovery were undertaken without an application to the reigning Pontiff for permission to annex all countries that were *not* Christian. It was argued 'that the successor of St Peter, as the Vicar of Jesus Christ, had the

power of disposing of such kingdoms as did not pertain to Christian potentates. The Popes, Martin V., Eugenius IV., and Nicholas V., had already invested Portugal with the empire of all the countries they had hitherto discovered on the coast of Africa. Alexander VI., to whom, after the voyage of Columbus, Spain and Portugal preferred at the same instant their pretensions, marked out a line traversing the two poles which divided the terrestrial globe.' This *line of demarcation*, as it was designated, passed through the first meridian laid down by Ptolemy across one of the Canary Islands. Hence arose the division of the world into the eastern and western hemispheres, which pertains to the present day, and is familiar to every tyro in geography." *

442. *Artificial Divisions in Geography have no relation to Natural Divisions.*—It will be apparent, therefore, to the most ordinary capacity, that these artificial occidental and oriental hemispheres have no relation whatever to the natural north and south divisions at the equator, especially with reference to the atmosphere and the vicissitudes of the seasons in the temperate zones beyond the calm-belts of the tropics, which form the leading subject of our work. Neither do the strictures of Humboldt apply to the geological disparity we have shown between the north and south hemispheres, inasmuch as it is chiefly the preponderance of elevated land in the former upon which we have based our theory of the origin of the seasons, as the result of internal terrestrial forces. At the same time, we cannot overlook the observations of scientific travellers in South America subsequent to Humboldt, whose evidence is in favour of our theory, that this continent was upheaved at a later epoch than the continental masses of the north hemisphere. The most recent observer, and the one best qualified to give an opinion on this point, is Professor Agassiz, who lately made a scientific journey in Brazil, and published to the world the startling announcement that he saw indications of extensive glacial

* 'Heroes of Discovery,' by Samuel Mossman.

action on the surface-geology of the country very little elevated above the level of the sea in tropical latitudes.

443. *Professor Agassiz on the remarkable Geological Phenomena of Brazil.*—"The existence of a glacial period," he remarks, "however much derided when first announced, is now a recognised fact. The divergence of opinion respecting it is limited to a question of extent; and after my recent journey in the Amazons, I am led to add a new chapter to the strange history of glacial phenomena, taken from the southern hemisphere. . . . In Brazil the moraines are as distinct and as well preserved in some of the coast-ranges on the Atlantic side, not more than twelve or fifteen hundred feet high, as in any glaciated localities known to geologists in more northern parts of the world. The snow-line, even in those latitudes, then descended so low that the masses of ice found above its level actually forced their way down to the sea-coast. . . . The valley of the Amazons was first sketched out by the elevation of two tracts of land—namely, the plateau of Guiana on the north, and the central plateau of Brazil on the south. It is probable that, at the time these two table-lands were lifted above the sea-level, the Andes did not exist, and the ocean flowed between them through an open strait. At a later period the upheaval of the Andes took place, closing the western side of the strait, and thus transforming it into a gulf, open only towards the east. Little or nothing is known of the earlier stratified deposits resting upon the crystalline masses first uplifted along the borders of the Amazonian valley. There is here no sequence, as in North America, of Azoic, Silurian, Devonian, and Carboniferous formations, shored up against each other by the gradual upheaval of the continent, although, unquestionably, older palæozoic and secondary beds underlie, here and there, the later formations. . . . Whether the Tertiary deposits are hidden under the modern ones, or whether they are wholly wanting, they have never been observed in any part of the Amazonian basin. Whatever Tertiary deposits are repre-

sented in geological maps of this region are so marked in consequence of an incorrect identification of strata, belonging in fact to a much more recent period. . . . Upon the lower set of beds rests everywhere an extensive deposit of finely-laminated clays, varying in thickness, but frequently divided into layers as thin as a sheet of paper. These clay-deposits assume occasionally a peculiar appearance, and one which might mislead the observer as to their true nature. When their surface has been long exposed to the action of the atmosphere, and to the heat of the burning sun, they look so much like clay-slates of the oldest geological epochs, that at first sight I took them for primary slates, my attention being attracted to them by their regular cleavage, distinct as that of the most ancient clay-slates. And at Tomentins on the banks of the Solimoes, in a locality where their exposed surfaces had this primordial appearance, I found in those very beds a considerable amount of well-preserved leaves, the character of which proves their recent origin. These leaves do not even indicate as ancient a period as the Tertiaries, but closely resemble the vegetation of to-day. The presence of such an extensive clay-formation, stretching over a surface of more than 3000 miles in length, and about 700 in breadth, is not easily explained under ordinary circumstances. . . . Occasionally the ferruginous materials prevail to such an extent that some of these beds might be mistaken for bog-iron ore; while others contain a large amount of clay, more regularly stratified, and alternating with strata of sandstone, thus recalling the most characteristic forms of the Old Red or Triassic formations. This resemblance has, no doubt, led to the identification of the Amazonian deposits with the more ancient formations of Europe. . . . A glance at any geological map of the world will show the reader that the valley of the Amazons, so far as an attempt is made to explain its structure, is represented as containing isolated tracts of Devonian, Triassic, Jurassic Cretaceous, Tertiary, and Alluvial deposits. "This is wholly inaccurate, as is shown in the above sketch; and, whateve

may be thought of my interpretation, it is my belief that all these deposits belong to the ice-period in its earlier or later phases. To this cosmic winter, which, judging from all the phenomena connected with it, may have lasted for thousands of centuries, we must look for the key to the geological history of the Amazonian valley. . . . It may be truly said that there does not exist on the surface of the earth a formation known to geologists resembling that of the Amazons. Its extent is stupendous—it stretches from the Atlantic shore, through the whole width of Brazil into Peru, to the very foot of the Andes. Humboldt speaks of it 'in the vast plains of the Amazons in the eastern boundary of Juen de Bracamoras,' and says, 'This prodigious extension of red sandstone in the low grounds stretching along the east of the Andes is one of the most striking phenomena I observed during my examination of rocks in equinoctial regions.' . . . The rocks here differ so much in external character from those of the north hemisphere, that the European geologist stands at first bewildered before them, and feels that the work of his life must be done over again. It is some time before he attains a clew to the facts, and brings them into harmony with his previous knowledge."*

444. *Geology essentially a Study of Extinct Vitality and Physical Activity.*—These profound observations upon the recent character of deposition presented by the stratified formations of South America certainly startle us from our dreams of European geological epochs, as indicated by the data of rocks and fossils. But geology is not merely a study of the superposition of strata upon amorphous rocks, or *vice versâ*, or the classification of organic remains imbedded in palæozoic formations. These are but stepping-stones across the stream of time—from the present to the past history of the earth—enabling us to explore the extinct regions of vitality, so that the geological philosopher may restore to our imaginations pictures of its former physical geography and natural phenomena. It has been well observed that

* 'A Journey in Brazil,' by Professor and Mrs Agassiz.

"Geology deals with the internal as well as with the external, with the past as well as with the present; lifts the veil from the extinct, and marshals in chronological order the long line of events, physical and vital, which constitutes the history of our planet from the current hour back to the remotest ages. All physical change, all vital relationship, all continuity of law and order, come within the range of its cognisance, requiring the minutest observation and the most exact and sequential reasoning. . . . And thus, where others would 'homeward plod their weary way,' the field-geologist has his thoughts carried away from the present into the far-distant past, gleaning a new fact in world-history at every turn, and calling up vanished aspects of sea and land by the magic wand of scientific deduction. The scenery of nature, which, to most observers, is a mere passive circumstance, and nothing more, is to him a thing instinct with a thousand activities and producing causes; and what in them is a mere transient gleam of admiration, becomes in him an enduring glow of the clearest understanding. Oh, the delight of the field-geologist as, seated on some craggy peak, he looks down on the hills and glens that surround him! It is not alone the presence of their beauty or wildness or grandeur that strikes him, as it must strike other observers, but the conscious knowledge of the agencies by which their aspects were produced, and the looking backwards in time through the long ages of change to which they have been subjected. That hillside, smoothed and rounded by the ice-sheet; that glen, with its lateral and terminal moraines, gouged out by the glacier; and that winding valley, eroded by aqueous and meteoric action, are each graven with a history which speaks to the eye of science, and makes these mountain solitudes rife with the presence of nature's powers and activities. To others it may be given to admire; to the geologist it is given to comprehend, and in that comprehension to enjoy the purest pleasure which a survey of the phenomena of nature can convey. . . . It is thus in the field that the student of geology obtains his fullest and

newest information, collects additional stores, and corrects former misconceptions." *

445. *Geological Dilemma of Theory and Observation.*—If so much can be said with scientific propriety of the limited field of geological observation among the glens and mountains of Scotland, how great, how vast are the explored and unexplored regions of the South American continent, where Professor Agassiz finds new stores of information to correct previous misconceptions of the true character presented by the deposits of Brazil! If we are to accept the apparently trustworthy evidence of an eminent naturalist—of extinct glacial action at the sea-level in equatorial latitudes—how can the conclusions it leads to be reconciled with the generally accepted theories of Lyell and others of the most advanced school of geology, who base their views upon the supposition that the present limits of the tropical zones existed throughout all epochs? They hold that from the tropical to the arctic climates which prevailed at different periods in the present temperate latitudes of the north hemisphere, the sun never rose above the horizon higher, or descended lower, at the solstices than it does now; and they advance the hypothesis that all the remarkable phenomena geology furnishes records of during these eras may be accounted for by different dispositions of the land above the level of the sea from what now obtains. As far as this theory applies to the middle latitudes of the two hemispheres, and in some measure to the higher latitudes of the north hemisphere, there are evidences in the geological record to support its possibility, although we take exception to its grounds of probability as insufficient. But if the evidence of glacial action in the valley of the Amazons—on the equatorial line itself—be supported by further data after investigation, it is clear that, at the present obliquity of the earth's axis, no conceivable alteration in the areas of land and sea could have effected a change of climate from the recent past to the present, equivalent to a removal of the arctic circle

* Valedictory Address of Dr Page, retiring President, Edinburgh Geological Society, 1868.

to the torrid zone. In this geological dilemma we step in with our astronomical data of a probable wide extension of that belt, based on actual diminution of the tropical zones, as a logical solution of the problem. Assuming that these extended five degrees beyond their present limits, we have shown that the climate probably approached that of Mars, where, upon the highest astronomical authority, glacial action in all probability prevails over that planet's surface more or less, from its poles to the borders of, if not within, its tropics. Here we conceive there is a clear solution of the problem, which might be mathematically demonstrated by the geometricians, if they accepted without prejudice our theory for the basis of their formula. That this may yet come about we confidently predict, as the exceptional phenomena of what we may appropriately term the "New World" of South America are unfolded to our view by future scientific missions—of which we hope that this of Professor Agassiz is the precursor—not only from the United States, but from European scientific bodies, in which those of Great Britain should take that active part which belongs to her associations for the advancement of science.

446. *Importance of Geological Deductions to the Body Politic and Government of a Nation.*—It may be considered by those who are inclined to overlook the advantages of science to the body politic, that it is a matter of small importance to the nation at large whether the continent of South America was or was not upheaved by deep-seated volcanic forces subsequent to the appearance of the northern continental masses above the sea. In contemplating this subject it must be remembered that, apart from the geological and meteorological questions involved, it refers significantly, in these days of violent earthquakes, to the permanent stability or otherwise of those regions where man has built up so many wonderful monuments of his civilisation in the great cities of Europe, Asia, and North America. In this respect the question not only affects the material progress of nations, but also the social, political, and religious institutions of all civilised communities. For

example, is it not something for the inhabitants of northern countries to obtain the most incontestable evidence that the great volcanic vents of this hemisphere are comparatively closed by the accumulation of refrigerated rocky matter at their orifices, which has so thickened the crust of the earth in these latitudes that they are permanently free from such violent earthquakes as recently devastated South America? Is it not something for science to assure the public mind of Europe of the comparatively permanent stability of the land, so that the aggregate population of some two hundred and fifty millions may live without dread of such awful catastrophes as those which befel the states of Ecuador, Peru, Bolivia, and Chili? Is it not something for the consideration of the inhabitants of the cities and seaports of European states to be assured that these great hives of industry and commerce enjoy comparative immunity from the dreadful oscillations of the land, and the overwhelming waves of the sea that swept away the once flourishing towns of Arica, Tacna, Arequipa, and Iquique? Is it not something for the three millions of people inhabiting the great metropolitan district of London to know, through the investigations of science, that their flimsy dwellings, radiating from St Paul's to a circumference of thirty miles, are on a foundation exempt from such terrific shocks as those that laid the cities of the Andes in ruins—of which, were but one of relative force to shake the valley of the Thames, the whole wilderness of bricks, and probably their gigantic edifice in the midst, would topple over like a child's house of cards, burying hundreds of thousands under the ruins? Is it not, then, something for the inhabitants of the most populous and wealthy city in the world to be assured of the permanent stability of their homes; and is it not something for the Government of this great realm to feel confident, through faith in science, that the material prosperity and resources of the United Kingdom will remain unimpaired by physical catastrophes for the due maintenance of its social and political condition? It has been well observed by Darwin, who speaks with authority, that "Earthquakes

alone are sufficient to destroy the prosperity of any country. If beneath England the now inert subterranean forces should exert their powers, which most assuredly in former geological ages they exerted, how completely would the entire condition of the country be changed! What would become of the lofty houses, thickly-packed cities, great manufactories, the beautiful public and private edifices? If the new period of disturbance were first to commence by some great earthquake in the dead of night, how terrific would be the carnage! England would at once be bankrupt; all papers, records, and accounts would from that moment be lost. Government being unable to collect taxes, and failing to maintain its authority, the hand of violence and rapine would remain uncontrolled. In every large town famine would go forth, pestilence and death following in its train." *

147. *Terrible Effects of the Earthquake at Tacna in Peru described by an Eyewitness, applied to the London District.* —Let the Londoner realise, if he can, the terrible effects that would follow such an earthquake as that which destroyed the town of Tacna—and let him suppose himself safe while witnessing its destruction of the devoted metropolis from the position of Hampstead Heath—from the following graphic account furnished by an eyewitness—an Englishman—resident at that town in Peru:—"On the fatal 13th August, at 4 P.M., I went to take my usual prandial walk; and following the water-course up through the town, I soon found myself out upon the broad gravelly plain that lies between Tacna and the mountains. I had gone nearly three miles out when I noticed some little heaps of boulders piled up on the plain, and thought I would take a look at them before returning to dinner. As I walked towards them I felt suddenly faint and giddy; the ground appeared to be moving under my feet, much like a badly-laid carpet that the wind gets under. In a moment more I found myself reeling and staggering in a strange and most alarming manner, and thinking I was about to swoon, I went quickly down upon my hands and

* 'Voyage Round the World.'

knees to save myself from injury in falling. At that moment I noticed stones shaken down from the little heaps of boulders I had started to examine, and then I became aware of a dull booming sound that seemed to be issuing from the entire surface of the great desert between the Andes and the sea, and, of course, I knew immediately it was an earthquake. I observed the time by my watch the instant I rose to my feet, — it was exactly two minutes to five. The ground, which at first had but one up-and-down movement, now began to shake rapidly and violently from side to side, and I found it so very difficult to keep on my feet that I preferred to go down upon my knees, thinking that I could observe better in that position, when my attention was not so much occupied by attempting to preserve my balance. I now distinctly saw the broad plain rising and falling in rapid pulsations, for I was looking towards a horizon of low hills (away beyond the town), with which I could compare the movements of the ground. I thought I could recognise distinct undulations coming from the direction of the Cordillera, and rolling down towards the Pacific Ocean. The subterranean thunderings which, although not very loud, sounded now so grand and terrible, also seemed to follow the same direction; but I cannot speak positively of either the one or the other, for at times it appeared as if the awful sound was diffused equally under the entire surface of the country, while the movements were sometimes complicated and varied in direction. A large old palm tree that grew near the water-course, at a distance of fifty yards behind where I was kneeling, was so violently shaken that the loud rustling of its large heavy leaves caused me to turn my head in that direction, and I now observed something very strange and unnatural about the aspect of the mountains, that hitherto I had not noticed, because my face had been turned towards the town. This was an appearance of dense clouds of yellow dust bursting from the steep mountain-sides, spreading and rolling along the entire western front of the first range of Cordillera, just as if the great Andes themselves were being rent and shaken

to pieces by some terrible convulsion. It was a truly wonderful but rather terrifying scene. At that moment the already frightfully-heaving ground began a new kind of movement more alarming than any I had yet felt—namely, a series of sharp upward jerks, as though the crust of the earth was receiving a succession of sudden and tremendous blows from beneath, causing loose stones to jar audibly against each other, and masses of gravel to fall from the banks of the dry water-courses. Then I saw some houses about a quarter of a mile off on the plain apparently crumbling away, and clouds of dust arising from their ruins. A similar but much larger dust-cloud now appeared boiling up from the city itself; and then the distant wailings of thousands of terrified people, the moaning and howling of dogs, and many other sounds of distress, were mingled with the awful and mysterious rumblings of the earthquake, that seemed to be increasing in violence every moment. Up to this time the only emotions I had experienced were a deep and most intense interest in the strange scenes enacting around me, and a certain feeling of quiet exultation in the thought that I should have been fortunate enough to witness such extraordinary phenomena. But the evident destruction that was going on in the city, and, above all, the terrible aspect of the mountains, now convinced me that it was a very serious earthquake, and I even thought it possible that we were about to experience some awful catastrophe—some convulsion of nature on a prodigious scale. I had no fears whatever for my own personal safety, for I felt pretty confident that nothing could injure me out on the plain, unless the ground should gape open just where I happened to be, which I thought exceedingly improbable. And yet I, who at first actually gloried and exulted in the earthquake, was now most keenly anxious for it to pass away, and leave us and the poor earth in peace; for it had now become altogether too serious not to be exceedingly alarming, and every succeeding shock, or rather blow, made me fairly wince. So I got down on all-fours again, and held on, "as it were, to the troubled ground, until, after one tremendous heave that

I felt sure must have overthrown every remaining house in the city, accompanied by a dull roar that I could hear rolling down towards the sea, the frantic movements ceased altogether, and I felt truly thankful that it was all over. . . . I now returned with all haste towards Tacna, full of anxiety as to the fate of the town. As I hurried along I felt, at the intervals of every few minutes, repeated *templores* of more or less severity; and at each successive shock renewed cries of terror came from the direction of the town. As I passed down the principal street I found it thronged with frightened people, standing, or more generally kneeling, beside the gutter in the middle of the roadway—women and children crying most piteously, men embracing each other, and sick people being carried out in ponchos. Every here and there the ruins of houses encumbered the way, while their late occupants appeared, some completely overwhelmed with grief, sobbing and crying bitterly; others bewailing with frantic cries and gestures the loss of their property; and others, more quiet and sensible, sitting disconsolately on the dusty heaps of rubbish that had so lately been their homes, the very picture of misery and despair. Eager men, with pale faces and wild looks, were searching anxiously for different members of their families, who at the first alarm had rushed out of the houses in all directions, and were scattered about the town. Wailing women were wringing their hands in their misery, and crying, as only women can cry, for their missing children; and terrified people of all sorts and conditions, driven crazy with fear, were comporting themselves in various strange ways,—some insanely screaming with pure terror, others laughing hysterically, others fainting and lying pale and apparently dead in the streets, but by far the greater number rapidly repeating prayer after prayer, vainly imploring their saints to protect them. And whenever the boom of a fresh shock was heard approaching, the whole populace would go down on their knees with one accord, and, with hats off and heads bowed down, would pray louder than ever, in their native tongue, 'Mercy, O Lord! mercy,

Mary, pure and holy! mercy, O Lord!' The terrors of that dreadful day, which appeared to the affrighted inhabitants as if the great day of judgment had arrived, and the earth was being 'gathered up as a scroll,' were not at an end, for as night set in the lurid glare of volcanic eruptions gave to the surrounding darkness a realisation of the visions in Revelations. In some cities what buildings the earthquakes and influx of the sea had spared were destroyed by conflagrations. Then famine stalked through the land; pestilence decimated the surviving inhabitants; and, as if it were necessary for the evil disposed among men to add the climax to the ruin and distress that prevailed, prowling bands of robbers ransacked the towns and villages, plundering the survivors of their remaining property."

448. *The Epoch of great Volcanic Violence has passed away from Europe.*— In view of probable calamities such as befel the doomed cities on the west coast of South America, is it not something for the inhabitants of Europe to know, upon the highest scientific authority, that, as far as human investigation can penetrate into the profound central regions of the earth, there is abundant evidence to conclude that the epoch of frequent, violent, and widespread volcanic activity in these latitudes has passed away? In confirmation of this doctrine we advance our theory of unequal ponderosity in the north and south hemispheres; wherein the former is not only heavier by reason of its greater elevation of solid matter above the depths of the sea, but below, the inner crust of the earth is in all probability thicker, or the internal volcanic vents of primary epochs made confluent, or flowing into domes of elevation, that resist more effectually the deep-seated sources of that power, which finds the weaker points of outlet in this era chiefly in equatorial and southern latitudes. It may be said that the great earthquake of Lisbon is an example in modern times that contradicts this view; also the numerous eruptions of Vesuvius during the past year. But we contend that these rather support our views of the distribution of subterranean forces than otherwise.

Compared with the convulsions of the land in South America, these were limited, not only in degrees of force, but in extent of area and frequency of action, during the three centuries that this region has been known to Europeans. Without going back to periods before the earthquakes of 1868, we may point out the comparative extent of country that would have been affected in Europe had these occurred in the north hemisphere. The line of action extended from Casma in Peru, 850 miles north of Arica, to Talcahuano in Chile, 1300 miles south of that central point of activity. As both of these towns at the extremes were greatly damaged by the earthquake, there is no doubt that the line extended beyond these points. Applying the ascertained length to Europe, we find that it would include the coast of the Continent from the North Cape to Cape Finisterre; and its lateral action of about 200 miles would include the east and west shores of the English Channel, with the cities of London and Paris near the central point of activity.

449. *Scientific Missions should be appointed by the State.*—If, therefore, there are any lingering doubts in the public mind as to the possibility of earthquakes of equal violence to the Peruvian *temblores* visiting our crowded cities, we trust that what has been advanced in this essay has aided in the assurance of the permanent stability of their foundations. Still the voice of a single individual is of small effect unless it mingles with those of others strengthened by authority. We might say that it lies within the scope of legitimate action for the Government to aid a scientific commission in this respect, where the public peace of mind is concerned, to investigate and report on the subject, as much as it would be to appoint a commission of inquiry into any ordinary social or political question. We hope to see the day when there may be a department of practical science in the State, as well as departments of trade and education. Meanwhile it would be advantageous to the nation in many ways, even on the score of sanatory improvements and the public health, to investigate the questions we have broached in this essay, by

means of a scientific commission sent to our colonies in South Africa, Australia, and New Zealand, and the anomalous regions of South America. Hitherto these investigations have been carried on chiefly by individual exertion, with occasional slender assistance from scientific associations. But now it would appear as if the time had come when it is necessary to supplement personal energy and service by grants from the public revenue. Excepting the prince of scientific travellers, Humboldt, few *savans* have been wealthy enough to carry out their investigations on a scale commensurate with the important objects of science. Where means have not been at the disposal of the naturalist to conduct his operations, he has been indebted to the generosity and munificence of others. Still the assistance looks like charity. A notable instance of this is seen in the mission of Professor Agassiz to Brazil, where, but for voluntary assistance, his labours would have been almost fruitless. We trust, therefore, that should a commission of that nature proceed from this country, it will be amply furnished with means by a free vote of Parliament.

450. *Different Effects upon Travellers of the Rarefied Air in the Andes and the Alps.*—As we progress in our knowledge of the physical geography and natural phenomena of the south hemisphere, further disparities may be recognised, at present unknown, as compared with those of the north hemisphere. Recently some French *savans*, on comparing the experiences of travellers ascending high mountains, have observed a singular disparity in the atmospheric effects on the human constitution. It is well known that, on ascending Mont Blanc or any other high mountain situated in the *north* hemisphere, the traveller experiences a considerable congestion of blood in the head, which manifests itself by the swelling of the face and lips, somnolency, and the emission of blood from the mouth, nose, and pores. In the *south* hemisphere an opposite effect is observed—instead of an apoplectic tendency, a general weakness, approaching to syncope, pervades the body, causing paleness, dizziness, fainting, and vomiting. Nor

are the means of affording relief the same, except that in both cases a horizontal position is considered advantageous. But no one in the northern hemisphere would think of administering to the patient the irritating poultices and exciting draughts invariably used in South America; and the Alpine tourist soon finds out by experience that the brandy he has taken with him rather increases than diminishes his indisposition. This extraordinary difference in the symptoms experienced in the two hemispheres cannot be attributed to the mere rarefaction of the air in the upper strata of the atmosphere, and must therefore be owing to some other cause. It has been attributed to the difference in electric influences. We are of opinion, however, that our theory of a disparity in the constituents of the south and north aerial hemispheres may account for the phenomenon, and the peculiar symptoms affecting the traveller through the mountains of the Andes may arise from the atmosphere being highly charged with carbonic acid gas in that region.

451. *Speculative Hypothesis on the Carbonic Structure of the Sun.*—Here the speculative philosopher, with his transcendental generalisations, might trace some connection between the carbonic element of the atmosphere in South America, the existence of carbon in its purest form in the diamond mines of Brazil, and its probable source in the sun itself. He might advance the hypothesis, that carbon is one of the indestructible elements that maintain the radiation of heat throughout the solar system, of which the central luminary is the mighty depository, from whence the comets, planets, and their satellites have derived their constituent atoms of its essence, arguing as follows:—If we infer that cosmical bodies in their nebulous form contained nitrogen as their basis, it is not unphilosophical to suppose, that when they assumed the indefinite form and erratic orbits of comets in their close perihelion round the sun, they absorbed a portion of its inflammable elementary structure. And presuming this consists chiefly of carbon and hydrogen as the combustible matter, with oxygen as supporting combustion, we may conclude

that these elements were derived from the sun, more or less at each cometic revolution, diminishing in the volume absorbed as their orbits contracted and their nuclei assumed planetary forms. We can suppose also that, as they received these elements in addition to those of their primary nature in a high calorific condition, as they swept round the incandescent centre of their system, they combined chemically with the azotic gas or nitrogen. Then as they rushed into boundless space, where the sun exerted little or no calorific influence over them—there, in the freezing darkness of years, the gaseous elements condensed into liquid and solid forms before they revolved again within the solar heat. Thus in searching for data to examine the primitive structure of the earth, it is not necessary that we should confine our investigations to the rocks and seas. With a more sublime and primary book before us, we should look above and around in the circumambient atmosphere, and through it, with penetrating eye and astronomical instruments, gaze upon and study the sidereal heavens, wherein appear cosmical bodies illustrative of its history from the beginning. Let us contemplate the sun, for example, in this manner, and consider its vast body, chiefly of carbonic structure. May we not consider its substance as generating a photosphere from which we derive all our light and heat necessary for existence—as obeying the same eternal laws that regulate combustion on this earth wherein carbon is the basis? As we gaze into the winter's fire, where the blazing coal or yule-log burns and brightens up our festive homes, we see, when its charred embers begin to show through the flickering flames, black spots amid the brightness in strange contrast. So may it be that the solar orb itself—whose magnitude astronomers inform us is nearly fourteen hundred thousand times that of our earth, and on whose incandescent surface black spots appear, shifting, contracting, and expanding like the charred surface of our blazing log—is a vast globe of solid carbon, with an atmosphere of hydrogen and oxygen in a constant state of combustion. And as the immortal Newton deduced from the alembic of his brain the fact which

Davy chemically demonstrated—that the diamond is only pure carbon—may it not be, if there are mountain-chains on the carbonic sphere of the sun, that in their glittering pinnacles piercing the fiery photosphere we behold vast diamonds—koh-i-noors—literally mountains of light, whose lustre dazzles the human eye at a distance of ninety-five millions of miles? With this conception of the solar radiance, how poor, how infinitesimal the brilliance of all the gems that deck the jewelled crowns of earthly monarchs, or the persons of earth's richest sons and daughters!

452. *Spectral Analysis of a Telescopic Comet seen in 1868.*—That such philosophical speculations regarding the abundance of carbon as an element of cosmical bodies is not altogether without actual data in its support, we shall quote the observations of a scientific writer in the 'Daily News' regarding the spectral analysis of a telescopic comet which appeared in the heavens during 1868: "On the 18th of June a comet was discovered by the German astronomer, Dr Winnecke, already known as the discoverer of a short-period comet which appeared in 1858. So closely are the heavens watched in the present day by the astronomers of Europe and America, that it is no uncommon circumstance to hear of new telescopic comets being discovered simultaneously by more than one observer. This was the case in the present instance—M. Bequet, of the Imperial Observatory at Marseilles, having detected Winnecke's comet independently on the same night as the German observer. The stranger soon increased in brightness, and became at one time visible to the naked eye. In fact, though not comparable in brilliancy with the comets which attracted public notice in 1859, 1861, and 1862, Winnecke's comet has surpassed in brilliancy all those which have made their appearance during the past five years. In the telescope it appeared as a nearly circular spot of nebulous light, in the centre of which there was a round nucleus from which a tail might be traced to a distance of nearly one degree. Mr Huggins quickly availed himself of this favourable opportunity for extending the

researches by which he has already thrown so much light on the structure of the celestial bodies. He found that in the spectroscope the light of the comet—like that of Brorsen's—was resolved into three bands; but these were much broader in Winnecke's than in Brorsen's comet—they were also differently situated. They were not of uniform breadth and brilliancy, but shaped somewhat like tongues of light, the pointed extremities being the least brilliant. The brightest band was in the middle, and appeared to spring at its brightest end from a sharply-defined line of light. In this case, as in the case of Brorsen's comet, only the faintest part of the comet had a continuous spectrum; so faint was this, that Mr Huggins was unable to speak positively of its existence."

453. *Determination by the Spectrum to have an Atmosphere of Volatilised Carbon.*—So far the observation of Winnecke's comet had presented nothing which differed in kind from what had already been learned respecting the cometary spectra. But now the time has come for the discovery of one of the most remarkable and significant facts which has ever been made known. We have already mentioned that Mr Huggins in 1864 examined the spectra of several terrestrial elements, and that he had noticed some among them which appeared to consist of bright bands. Amongst the diagrams he had made at that time he now found one which seemed to present a very close resemblance to the spectrum of Winnecke's comet. This diagram represented the spectrum of carbon, as seen when the spark from an induction coil is taken through olefiant gas. In this gas, as many of our readers are doubtless aware, there are six parts by weight of carbon to one of hydrogen. The spectrum of the light of a spark sent through the gas presents, of course, a combination of the spectra of carbon and hydrogen. But it is easy to distinguish the one from the other, since the bright lines belonging to the hydrogen spectrum are well known to spectroscopists. In the spectrum of the comet, as we have seen, there were no bright lines, so that

it was in order to determine whether the comet consisted wholly or mainly of volatilised carbon that Mr Huggins proceeded to the direct comparison of the spectrum of carbon with that of the comet. Dr Miller, F.R.S., the eminent chemist and spectroscopist, whose name has already been associated with that of Mr Huggins in researches of this sort, was present, and took part in the observations which were made. "A glass gasholder, containing olefiant gas, was connected by a flexible tube with a glass tube, into which the platinum wires were soldered. This tube was so fixed that the spark between the wires was suitably reflected into the spectroscope attached to the telescope; so that the spectrum of carbon appeared directly below the spectrum of the comet." The two physicists were perfectly satisfied that there was no perceptible difference between the two spectra. The bands were not merely coincident in position, but in their general character and in their relative brightness. On a subsequent occasion, Mr Huggins repeated the experiment with an equally satisfactory result.

154. *Remarks on a Concentration of the Physical Sciences into one "Great Science."*—"We are compelled, then, to accept as an inevitable conclusion from those observations the fact that Winnecke's comet consists either wholly or mainly of volatilised carbon! How it is that a substance which is so fixed in its nature as carbon can be volatilised in the interplanetary spaces it would be exceedingly difficult to explain. In the case of a comet like the one of 1843, which approached the sun within a distance of about 60,000 miles, one could comprehend the volatilisation of any known terrestrial element. The heat to which that comet was subjected was equivalent, Sir John Herschel tells us, to that which would be experienced if there were 47,000 suns in the sky, each equal in magnitude and brilliancy to our own Sun. But Winnecke's comet did not approach the sun near so closely as this. When Mr Huggins was observing it, it was at least as far from the sun as our earth; and it seems difficult to understand how at that distance from the sun its substance

should be heated so intensely that such a substance as carbon should be volatilised. The fact, however, remains; and we are beginning to learn that what is intelligible to us must not be accepted as the measure of that which actually exists in nature. The more widely we extend our researches, the wider becomes the boundary of the unknown; and each explanation of known facts brings with it a hundred difficulties which remain inexplicable. At present we must be content to accept the important discovery which Mr Huggins has effected, without expecting that we shall be able at once to explain its meaning. Perhaps before long other discoveries may be made which will dovetail into this one. The astronomer, the chemist, and the geologist, no longer work alone. A universal science is springing into existence, which includes the results obtained by labourers in many fields of research. Unfortunately there is still a want—a want which we are not likely soon to see supplied; we want a Humboldt, with all a Humboldt's powers intensified fifty-fold, to bring the sciences of man into due correlation *inter se*, and to evolve from them, and carefully to co-ordinate, the principles of the 'great science' of the future."

455. *Reflections on the desirability of accomplishing that Object.*—Thus it may be said that we are only on the threshold of our knowledge concerning the whole arcana of the physical sciences in determining the unexplained wonders of creation. In these interesting experiments we see how chemistry steps in to solve an astronomical problem never dreamt of by Newton or Galileo, in whose time that science was little better than a jumble of empiricism. In like manner we trust that what we have advanced on geological principles to account for the remarkable physical phenomena observable on the earth, as vestiges of its past history, will aid in cementing the youngest of our sciences with the ancient and venerable study of astronomy. There are other sciences, no doubt, that will in time add their quota of discovery to the "grand science" that is likely to arise out of their general concentration; but in order to render their application

available towards the desired end, it is absolutely necessary that all prejudices and jealousies should be set aside for the accomplishment of the one great object in view.

456. *All Nature proclaims a Principle of Physical Binary Division dual in Phenomena.*—In conclusion: When we contemplate the aspect of the earth revolving in space as a great cosmical body, with its solid framework of rock covered two-thirds by water and completely enveloped in air, it is not inconsistent with nature to find that these elements are subject to binary laws under one universal system. In the inorganic world there is a system of compensation which gives on the one hand and takes on the other. Thus the structure of our planet may be one and indivisible, but the disposition of its solid parts is unequal, from whence arises its sublimity and utility. There are no two parts of its compound substance alike, yet all is homogeneous, forming one grand whole. In like manner the boundless ocean presents a general uniformity and continuity, yet we know that it is divided into many subsidiary seas presenting great variety of feature, with two separate systems of currents. But it is in the organic world that we find the binary divisions of nature in perfection. Every leaf that forms the foliage of the forest has its subdivisions, apparently the same exactly on each side the midrib, yet on close inspection there is a disparity between one half and the other. And so also every fish, bird, or beast is double in its structure, forming animated systems of compensation, one of which can support life in the whole should the other become disarranged. On this principle it is as consistent to hold that there are two great currents of the ocean, one flowing south of the equator and the other north, as it is to say that the circulation of the blood is separated into two branches ramifying to the extremities, right and left of the spine; or that the binary division of the atmosphere herein expounded is compatible with the fact that we have a pair of lungs for the purpose of respiration. Thus it would appear that, as all the organs and functions of the animal structure are dual in their nature, so the solid, fluid,

and gaseous structures of our common mother-earth, especially the atmosphere that furnishes the life-giving element to her children, are binary in their physical phenomena.

457. *Concluding Remarks on the General Subject of the Work.*—With these comprehensive remarks on the philosophy of our theory, we have reached the last phase of the changeful subject, and, like the vicissitudes of the seasons in their annual course, return to the point from whence we set out. Having gone, as it were, round the orbit of our theory, we have passed through the spring, summer, autumn, and winter of investigation, arriving again at the "gentle" season to survey the general principle herein set forth. With the "ethereal mildness" of the poet we submit it to the consideration of the reader learned in the exact sciences, as a compromise between astronomy and geology in accounting for the primary cause of the seasons and other unexplained phenomena in the past history of the earth. While astronomers have hitherto represented our planet as dependent solely on the perturbations of other cosmical bodies for these wondrous changes, we have endeavoured to show that within its own spherical shell lay the forces that impelled it into new activity after its primordial formation. Viewing it in this light, the world is not that inert mass of matter which we were led to believe, tossed about as a lifeless terrestrial ball among the other members of the planetary system. We have seen how these internal volcanic forces, acting with tremendous violence on the external crust, drove the earth from its normal position in the ecliptic, causing various degrees of obliquity between that and its equatorial plane, which may account for the most inexplicable epochs divulged by fossil remains; and we have also shown that these external changes in its configuration and rotation have probably brought about vital alterations in the atmosphere, which, under the influence of the solar heat, were the ORIGIN OF THE SEASONS.

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